

DIGITAL CONTROL AND DATA ACQUISITION
SYSTEM FOR TRISONIC WIND TUNNEL OF
AERO. ENGG. DEPT. OF I. I. T. K.

By
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DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

AUGUST, 1978

DIGITAL CONTROL AND DATA ACQUISITION
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A Thesis Submitted
in Partial Fulfilment of the Requirements
for the Degree of
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By
SQN. LDR. P.C.S. RAUTELA

to the
DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR
AUGUST, 1978

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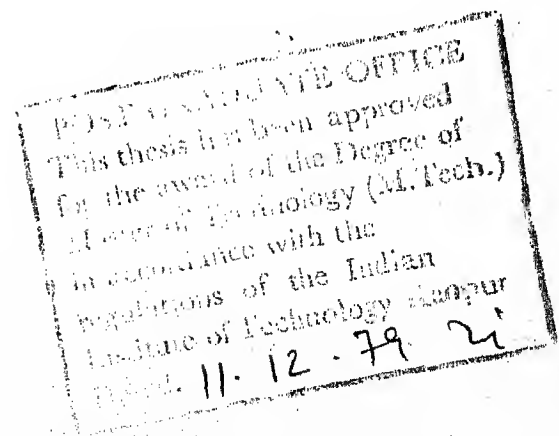
This is to certify that the thesis entitled,
"Digital Control and Data Acquisition System for a
Trisonic Wind Tunnel" by Sqn. Ldr. P.C.S. RAUTELA, is
a record of work carried out under my supervision and
has not been submitted elsewhere for a degree.

Kanpur
30th July, 1978

H.V. Sahasrabudhe

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Professor of Computer Science &
Electrical Engineering Department
Indian Institute of Technology
KANPUR



dedicated to the memory of

Late Miss Tokako Imoto

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- P.C.S. Rautela, Sqn.Ldr.

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ABSTRACT

This thesis describes the design and implementation of a Digital Data Acquisition and Control System for the Trisonic Wind Tunnel under installation at the Aero. Engg. Dept. of I.I.T. Kanpur. The controller coordinates the various control instruments in the wind tunnel such as valves, probes, model attitude gear, optical equipment etc. in real time. It acquires data from various sources of analog and digital inputs with respect to control parameters. Provision has been kept for expansion and improvement of the system for greater accuracy.

1. INTRODUCTION

The aim of the thesis is to design and implement a digital data acquisition and control system for the trisonic wind tunnel automation. The function of this system is to control various parameters of the wind tunnel and acquire experimental data all in real time.

1.1 Definition of Process:

A trisonic wind tunnel is under advanced stage of fabrication at Aero. Engg. Deptt. of I.I.T. Kanpur. The relevent details of the wind tunnel fabrication have been given in Fig. 1.1. Till now aeromodels were being tested on slower manually operated wind tunnels which limited the volume and quality of data acquired due to time criticality of the experiment. The new trisonic wind tunnel of I.I.T. Kanpur will be the first in the country to have a computer control and data acquisition which is based on PDP 11/03. The digital controller controls the operation of main and regulator valve, probe and model movement, camera and flash operation. Data is acquired through fast Analog To Digital Converter and parallel BCD inputs. The test object is mounted in the tunnel working space on a support called sting which is given the directional

movement by stepper motor based attitude control gear. Initially only pitch control is being implemented. The probe for pressure measurements in tunnel working space is moved in Y direction by a stepper motor based linear gear system. In the experiment which lasts for about 20 seconds, measurement of aerodynamic forces on the model (surface, temperature and pressure in the tunnel working space and flow pattern observation and photography through a Schlieren optical system is done.

The transducer probe for pressure measurement is halted to each grid point as defined in the initial parameters, its reading is taken through A to D converter and it is moved to next grid point. The model incidence is fixed by means of a stepper motor attitude control gear system for which initial and incremental pitch are defined. The aerodynamic forces on model surface are measured through scanivalve assembly. Temperature is measured by a fixed platinum resistor probe through a temperature module giving BCD output.

1.2 Operation:

The conditions of the experiment are set interactively by the user by way of defining requisite number of parameters. These parameters are duration of the experiment, number of

pressure and temperature probe readings, number of camera snaps to be taken, initial and incremental pitch. These details are entered through Decwriter console. The computer then determines the timing events and pulse sequences. Thereafter computer checks the readiness of various sub-assemblies e.g. amplifiers, power supply, valves, probes etc. This is followed by amplifier zero offset and calibration, storing the gain for future reference. Once the system is ready in all respects command for opening of main valve is issued, computer waits for full open indication and issues command to open the regulator valve. (This valve is separately preadjusted to meet the required regulation using its own control panel). Thereafter a delay of 10 seconds is given to reach steady state flow conditions. Now our controller starts the programmable clock for its count down schedule for next event. It takes the first set of temperature and pressure probe readings (the initial probe and model position is fixed before the experiment starts). The camera and flash is energized. The probe and model attitude is now changed to new positions. Now the computer waits for next time event to take place thereupon the cycle repeats. The scan valve is given a command to lock its ports at the scheduled time. The experiment stops after the

required number of readings in given time frame are over. Now the scanivalve data is collected through its transducer multiplexer system. The data collected is in BCD format for 48 ports. This data and temperature data both of which are in BCD format are now converted to correct decimal value and stored. The data after manipulation is stored in a floppy disc file. At present only single job environment of Real-time 11 operating system is being used. completed program is in BASIC which can be easily modified by inserting the proper line number. Thus flexibility is maintained.

REMARKS: 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 84

2. COMPUTER & PERIPHERALS SELECTION

The Aero. Engg. Dept. received proposals for computer systems capable of control and data acquisition as listed in Table 2.2. The general criteria for selection were as follows.

2.1 A dedicated Digital (Computer with following facilities.

- i) Fast data acquisition up to a maximum of 200 samples per second from digital and analog sources.
- ii) Fast Random access primary memory of at least 16K words and at least 500K of secondary bulk storage memory with access time not exceeding 10 m.s. (track to track).
- iii) At least 16 bit digital I/O, minimum 8 channels of analog inputs 0 to $\pm 10V$ with at least 12 bits of resolution.
- iv) DMA option and add on module capability for future expansions.
- v) Programmable real time clock and at least one level of interrupt facility.
- vi) Capability to hook on to larger systems of I.I.T. Kanpur to expand/share resources.
- vii) Cheap and reliable I/O device availability with the system.
- viii) Higher level language support of Fortran-IV/Basic with Real time operating system.

TABLE 2.2

1	2	3	4	5	6
Proposed System	Word Length	Interrupt	Pr.Memory	Secondary Memory	I/O Device
1. Computer Automation Nacked Milli A-LSI3/0 5E	16 bits	Yes	16K words	512K words	ASR-33 PTR
2. Computer Automation Naked Mini- LSI-2/20	"	16 level	"	"	"
3. Intel System 80/20 Microcomputer	8 bits	8 level	4K words	"	"
4. DEC Lab 11/03 Package minicomputer (LSI 11/03)	16 bits	1 level	16K words MOS	"	"
5. HP 3052 A-Aut- omatic data Acquisition system with 3437A voltmeter scanner 3455A Digital voltage 9825A calculator	-	-	7K	250K casset	Calculator console & character printer
6. HP 3050B - Automatic data acquisition system with 3495A voltage scanner 3490A Digital Multimeter 8390A Programmable calculator	-	-	7K	"	TTY & PTR

TABLE 2.2 contd.

Proposed System	7 Programmable clock	8 Options	9 Language and O/S	10 Remarks
1. Computer Automation Nacked Milli- A-LSI3/0 5E	Yes	DMA DI/O A/D D/A	BASIC Fortran IV Real Time O/S	
2. Computer Automation Naked Mini- LSI-2/20	Yest up to 10 KHz	16 bit Digi- tal I/O, 32 bit Relays.	"	
3. Intel System 80/20 Microcomputer	Interval/ event counter Two.	Synchronous/ Asynchronous interface, Serial I/O- Parallel I/O-48, A/D-42 bits	PL/M	
4. DEC Lab 11/03 Package mini- computer (LSI 11/03)	Yes upto 10 MHz	ADC 12 bits DAC 16 bit parallel I/O, DMA 2000 samples per second max. 6000 samples.	BASIC FortranIV APL Real time O/S	EIS, FPIS, Scientific subroutine package & direct hook on compatability to DEC system
5. HP 3052 A-Auto- matic data Acquisition system with 3437A voltage scanner 3455A Digital voltmeter 9825A calculator	Digital clock	Buffered I/O HPIB, Plotter	HPL	Only data acquisition system no controls.
6. HP 3050B Automatic data acquisition system with 3495A voltage scanner 3490A Digital Multimeter 8390A Programmable calculator	Digital clock	10 channel Relay actuator group	HP Basic	Relay outputs only with data acquisition

- ix) Off the shelf compact rigid model to suit lab applications, no need of special dust filtering, operating at 230V $\pm 10\%$, 50 cycles $\pm 2\%$, temperature range up to 100°F, R.H. 80%.
- x) Reliable after sales service with spares support.
- xi) Must fit with-in the financial constraints of Foreign Exchange release.

2.3 A critical evaluation of the proposals in Table 2.1 and their technical summary showed similarity of characteristics in all systems except proposal no. 5 of HP which was purely data acquisition system and proposal no. 6 had limited relay control available. Besides HP systems are calculator based thus limiting their capability. Dec PDP 11/03 meets all the criterias of O/S, languages, timing, environmental and financial constraints. Although similar systems of proposal no. 1 & 2 were slightly cheaper, the Dec proposal no. 4 was available in compact Lab package form. Already about 45 PDP systems are installed in India thus insuring after sales service and spares availability. It is known to be reliable system as many such systems are under use in defence installations who are known for their environmental specs. It also meets future hook on capability to proposed Dec 10/90 system of computer centre.

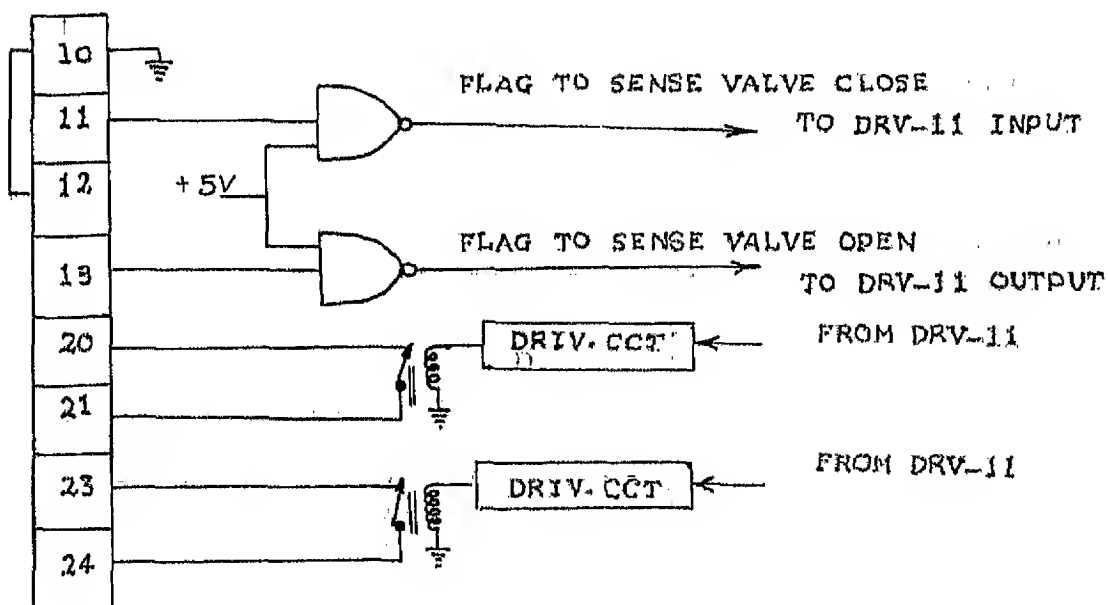
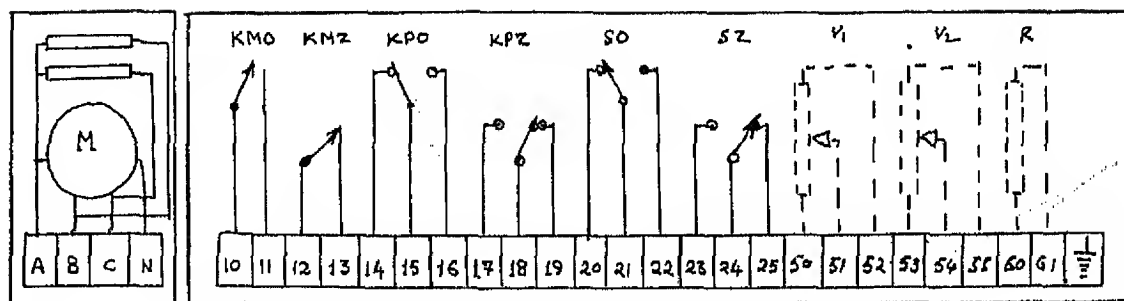
LA-36 is a fast reliable I/O device adjustable from 50 to 300 bauds taking adjustable paper width. pdp 11/03 is LSI based uses all instruction of pdp 11 family. Its memory can be expanded and modules can be added on. (Details of A/D, D/A converters, parallel I/O, clock modules of pdp 11/03 are given in Appendix A, and other hardware in Chapter 3).

3. DEFINITION OF HARDWARE

This chapter includes details of wind tunnel hardware associated with computer which were designed/fabricated or purchased during the work on this thesis. Relevant IBM-1800 DACS hardware has been briefly touched in Chapter 5 pdp 11/03 hardware details have been given in Appendix A.

3.1 Main Valve (Gate Valve/Isolator Valve)

This valve has been manufactured by BHEL. This valve isolates the high pressure storage tanks from test section (Ref. Fig. 1.1). This valve connects the storage tanks to tunnel working space through a regulator valve. The valve gate is driven by a servo controlled three phase AC motor. Servo system has inputs for remote operation. The valve open/close position is indicated by Torque switches (Ref. Fig. 3.1). The full open/closed indication has been used for giving indication to the computer for relevant flag checks. This is changed to TTL level through nand gates configuration. At present only full open indication has been provided to the parallel I/O DRCSR bit No. 7 for full open sense. Later on when the control console is ready it is proposed to provide the ready flag also for automatic check of the readiness of valve subassembly.(Ref. AP. A Fig. 1.4).



KMO- TORQUE SWITCH FOR POSITION OPEN
 KMZ- TORQUE SWITCH FOR POSITION CLOSED
 KPO- TERMINAL SWITCH FOR POSITION OPEN
 KPZ- TERMINAL SWITCH FOR POSITION CLOSED
 SO- SIGNALLING SWITCH FOR POSITION OPEN
 SZ- SIGNALLING SWITCH FOR POSITION CLOSED
 V1, V2- RESISTANCE TRANSMITTER 1/100 OR 2/100 Ω
 M- MOTOR
 B- BRAKE

FIG. 3.1 (REV) MAIN VALVE INTERNAL WIRING DIAGRAM FOR SERVOMOTORS
 AND SCHEME TO HOOK ON TO DRV-11 OF PDP 11/03

3.2 Regulator Valve

This valve has been manufactured by NAL with the remote control panel. The valve regulates constant flow of air through tunnel working space during the 20 seconds experiment. The parameters for regulation, permissible error is set at the control panel which has also visual indication to show the current flow and tank pressure. This valve takes 10 seconds for achieving steady state condition of flow for which the software system makes provision. The computer only commands the opening of this valve thereafter complete control is maintained by its own hydraulic regulator system. Ready sense is proposed through nand gating (Fig. 3.1), which will be introduced after the control console is planned.

3.3 Tunnel Working Space:

Tunnel working space is a 7" x 9" section where the test model, temperature and pressure probes are mounted. The temperature probe is permanently fixed to a position. The pressure probe has a transducer which is moved up and down in y direction. The model is mounted on an attitude control gear (only $\pm 18^\circ$ change in attitude permissible from horizontal position due to limited space). The two sides of the tunnel working space are

provided with transparent windows for observation/photo-graphy and schlieren optical gear. (Ref. Fig. 1.1).

3.4 Scanivalve Subsystem:

The system has been manufactured in USA and assembled by NAL with provision for signal conditioning and amplification. This is a 48 port model for the pressure range of 0.01 psi to 500 psi. The output is available in BCD 4 bit format for both the pressure and port number. It has 24V DC solenoid motor drive 24 ports cutoff valve (Qty. two) with an autoscan rate of 5 ports/sec. or 2 ports/sec. or 1 port/sec. Due to this limitation it is proposed to collect data after the experiment is over.

The scanivalve is a pressure multiplexing system capable of sequential scanning of upto 48 unknown pressures using a single high precision pressure transducer. The multiplexing system was developed to save the cost of multiple transducers (each \$ 400).

The system consists of a pressure multiplexing unit, a multiplexer control unit, a digital voltmeter and optional digital printer. The pressure multiplexer unit is capable of remote control which is proposed to be done by the digital controller. The unknown pressures are connected to the system through the pneumatic input pipes.

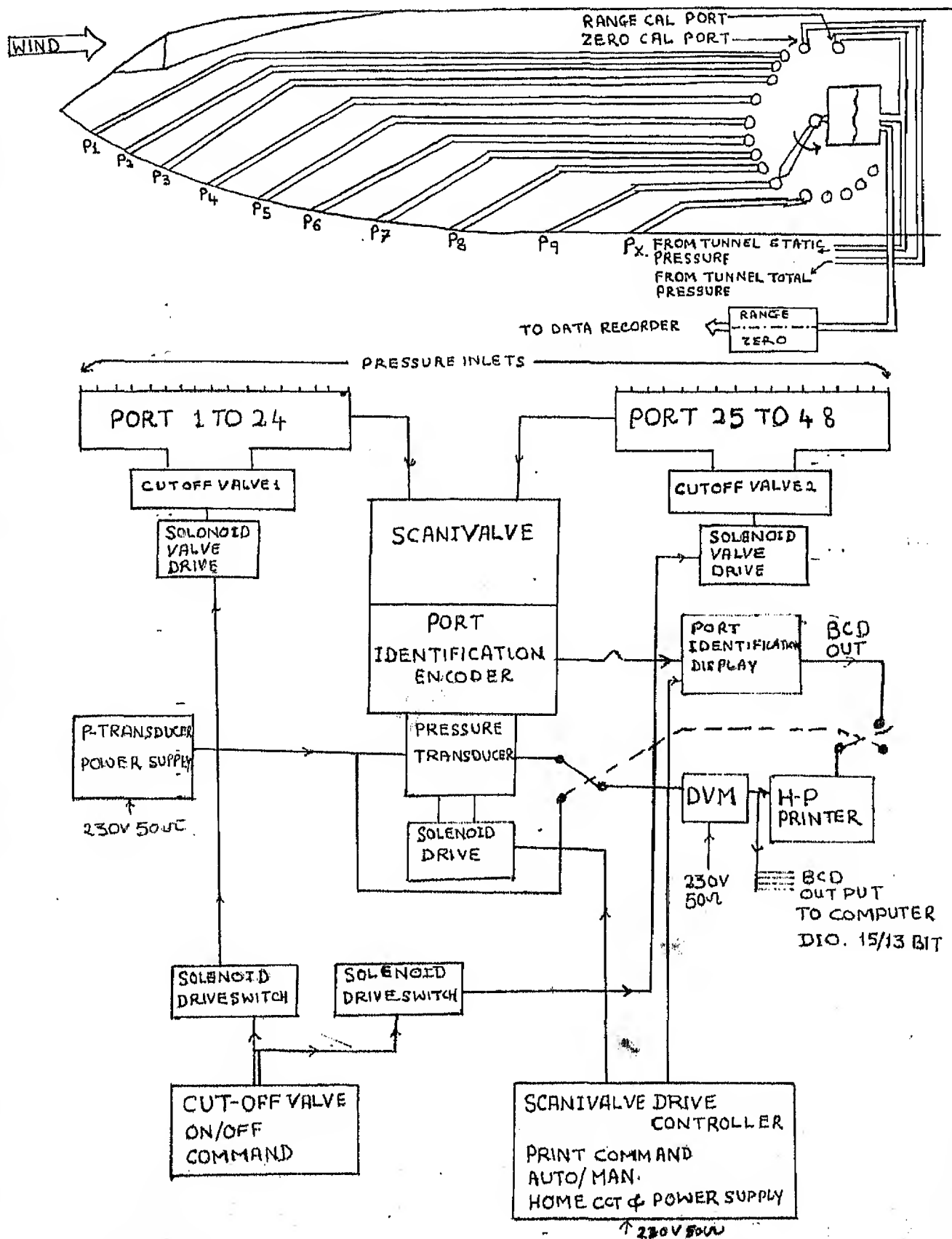


FIG 3.2 SCHEMATIC CIRCUIT DIGRAM OF 48 PORT PRESSURE
MULTIPLEXING (SCANIVALVE) SUB SYSTEM

These inputs are internally plumbed to two cutoff valves which are 24 way on/off pneumatic valves. The outputs of the cutoff valves are connected to 48 storage volumes for pressure trapping. The other end of these volumes are connected to scanivalve. These storage cylinders are scanned one by one by the pressure transducer fitted in the static assembly giving proportional electrical output. The electrical output is through a bridge, it is conditioned, amplified and displayed on the DVM. Both pressure and port identification are available in BCD format which are being interfaced to the input buffer of DRV-11, 16 line input. The DVM can also be switched on to read transducer excitation voltage for accurate calibration. All necessary control signals are generated in the system (Ref. Fig. 3.2 & 3.5).

3.5 Temperature Sense Subsystem:

This is a dedicated subsystem of Camare Electronics England. This system uses a platinum wire resistance of 100 Ω for sensing change in temperature. The unit is calibrated at 0°C standard. The subassembly except the element is being imported from the manufacturers. The unit consists of a regulated precision DC power supply source for element excitation, balance bridge, signal conditioner, amplifier and display unit. It has the option for BCD - 4 digit +Ve logic output format. This output is being

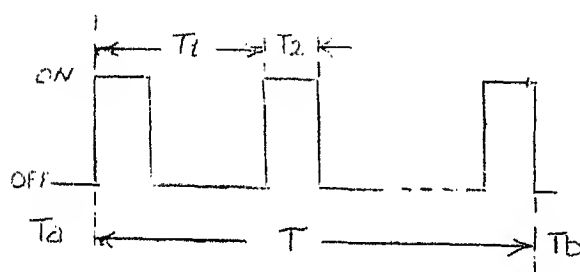
connected to DRINBUF of DRV-11 for acquisition purposes. The controller issues a hold signal to this unit while the data is being acquired by the computer to avoid change of reading. The unit gives an accuracy of $\pm 0.1^{\circ}\text{C}$ with 0.1°C resolution with a reading rate of 5 readings/second. It also provides sign indication.

3.6 Camera/Flash Subsystem:

For provision of observation and photography the tunnel working space has been provided with two sides of transparent windows. The schlieren optical system arranges for the illumination of the model, reflection of a coherent light beam. The reflection of the object can be seen on the glazed glass window screen, The photograph of the test model and flow pattern can be taken at scheduled intervals.

Cannon F.1 camera with motor drive mainframe has been selected for automated photography. This is a 35 mm single reflex focal plane shutter camera (1 to $\frac{1}{2000}$ of second speed). The main frame motor drive has been added to facilitate rapid advance of the film enabling 3.5 frames/second exposure. The unit is self contained for power. It provides facility for remote control through its timing unit which has been derived through computer output. The

The remote input has been connected to OUTBUF of DRV-11 to bit No. 15 for camera and bit No. 14 for flash. The required timing pulses which are critical for operation have been generated through software routine. (Ref. Fig. 3.6 & 3.8).



- T_a Start time - '0' ref.
 - T_b Stop time - 20 seconds.
 - T Total length of operate time - 20 seconds.
 - T_1 Settling time for one shot $\frac{1}{3.5}$ seconds.
- Continuous shot line.

Figure 3.8

3.7 Traverse Gear Probe Subassembly:

This subsystem is used to move the pressure transducer probe up and down along the y axis. (The software has provision for 4 degree of movement freedom). The probe is mounted on the down-stream portion of the tunnel working space. Stepper motor configuration has been utilized for the movement of probe through linear translation gear. Stepper motor has been chosen for easy and precise control through computer generated control pulses. The stepper motor takes 200 steps to make one revolution i.e. $1.8^\circ/\text{step}$. The

translator has been fabricated and tested with the help of control signals from IBM-1800 based program. The digital controller generates a train of pulses of required width at scheduled timing intervals through its digital output module. This is fed to the motor controller. The speed of the motor and direction can be altered without hardware intervention. One bit output i.e. bit 01 of OUTBUF has been kept for direction control ('0' for forward and 1 for reverse direction). The bit '0' controls the number of steps to be moved by giving output of the required number of pulses. The two bit output of the computer is fed to a hardware sequence generator which is made of two D flip flops synchronously clocked. The Q_1 , \bar{Q}_1 and Q_2 , \bar{Q}_2 outputs are fed to driver stage before applying to the motor winding. During trial it was found, for smooth hunt free operation of motor a pulse of 9 ms with 3 ms difference between two successive pulses is required. (This test was done for a 100 step motor). Details of the circuits and pulse configuration is given in Fig. 3.6 and Fig. 3.7.

The input from the probe transducer balance bridge is given to signal conditioner and instrumentation amplifier for direct input to A/D converters of pdp 11/03. The amplifier is calibrated before the start of the experiment and its zero offset is set. All ICs have been used (Ref. Fig. 3.4 and 7.7).

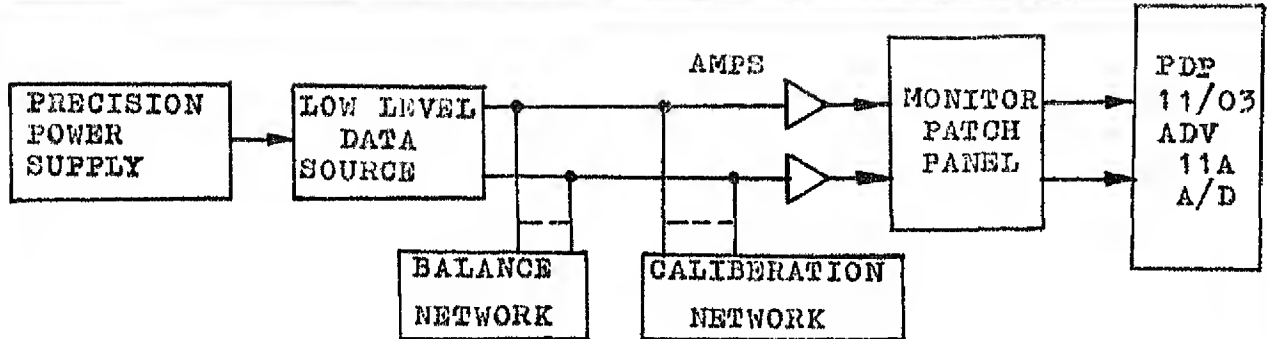


Fig. 33 ANALOG DATA SUB SYS BLOCK DIG

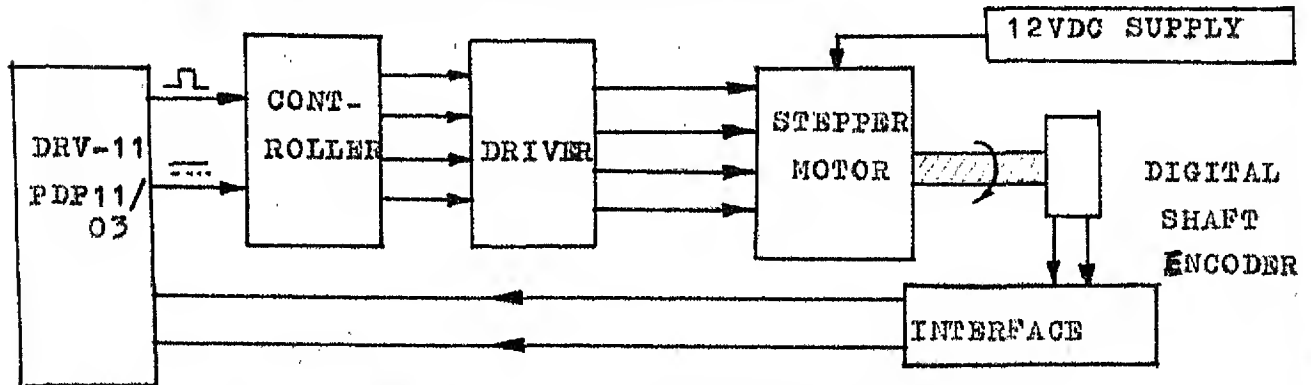


Fig. 34 STEPPER MOTOR DRIVE SUB SYSTEM BLOCK DIG

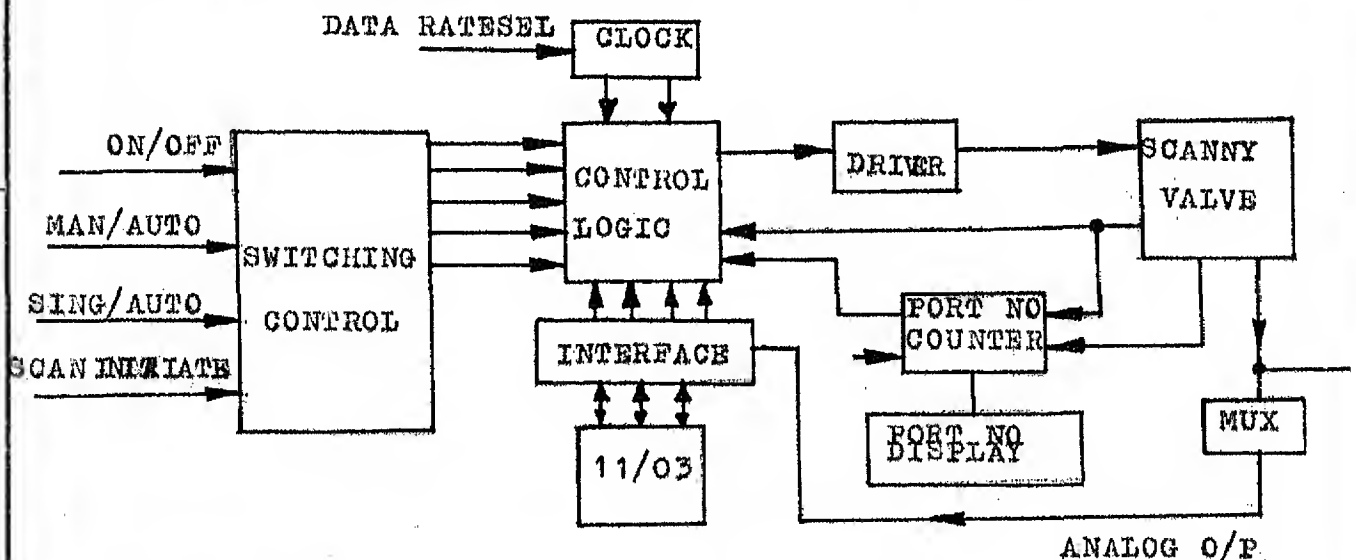


Fig. 35 SCANNY VALVE SUB SYS BLOCK DIAGRAM

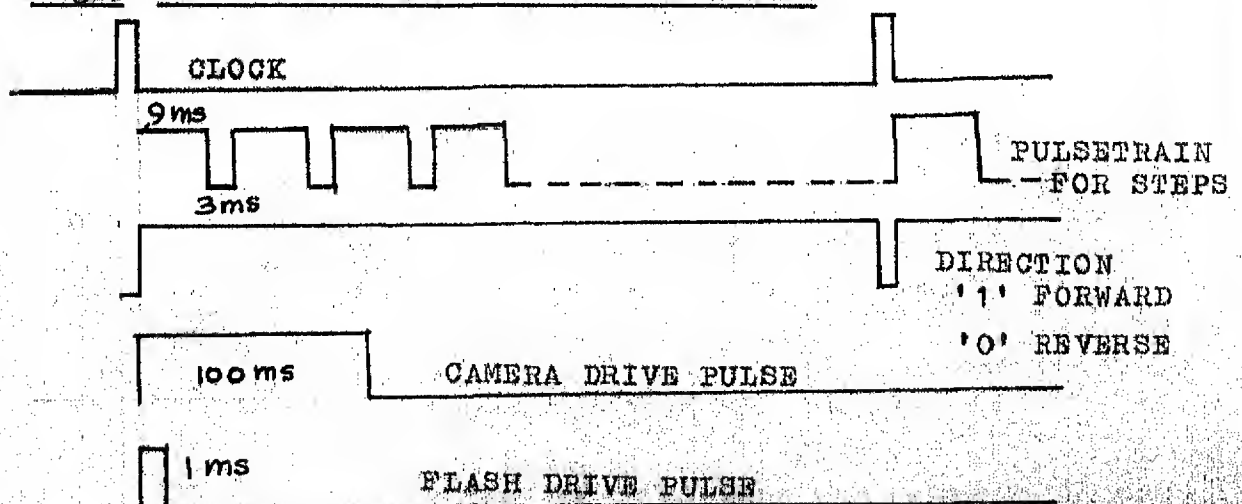


Fig. 36 PULSE FOR MOTOR CONTROLLER CAMERA, FLASH

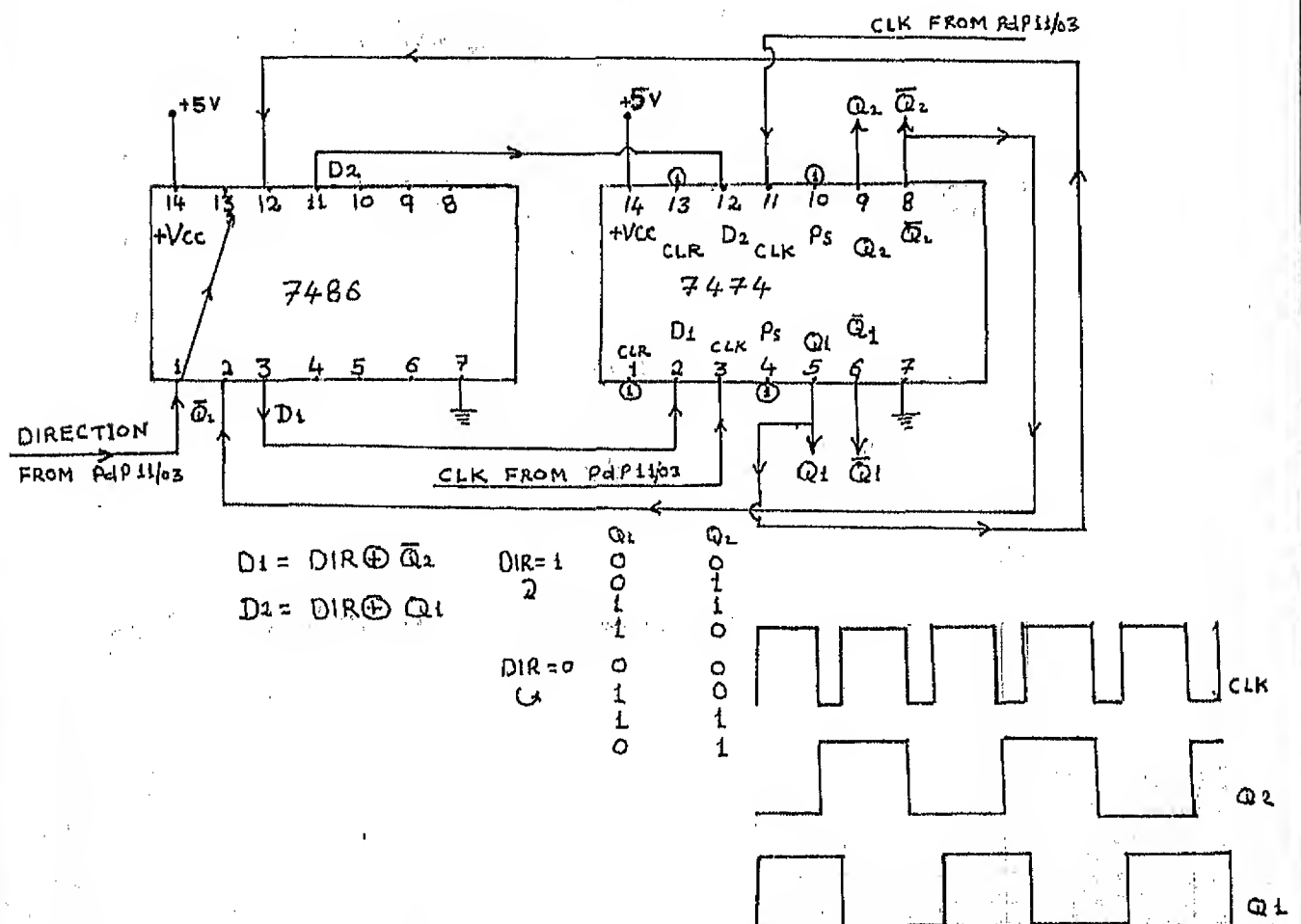
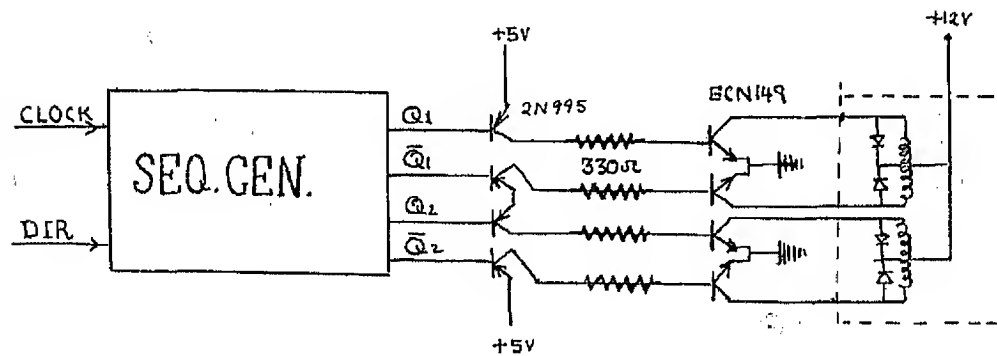
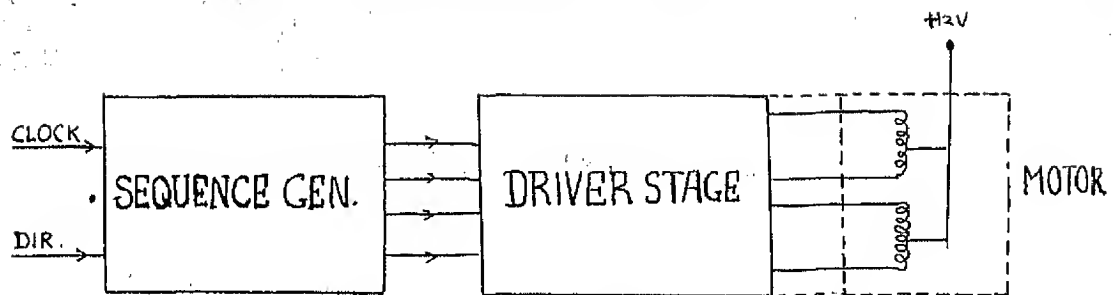


FIG 3.7 STEPPER MOTOR CONTROLLER

3.8 Model Attitude Control Gear:

The test model is mounted on a support controlled by model attitude control gear. This gear system is designed to change the pitch of the model aircraft. The model is given an initial pitch and is moved to next pitch point as defined by a parameter of incremental pitch. Due to limited space of 7" x 9" tunnel a maximum movement of 10 steps in either direction of horizontal reference line has been restricted. Earlier it was proposed to use a heavy duty A/C motor controlled through Analog O/P of computer but with the availability of higher Torque stepper motor the later has been selected. This becomes necessary due to high aerodynamic forces on model surface. A reduction gear further will give 10 times more Torque output at model control gear. The drive and control circuit for stepper motor remains the same. DROUTBUF bit No. 7 and 6 have been allotted for directional and step control of the motor respectively.

3.9 Digital I/O Interface to pdp 11/03:

This is used to give outputs to control camera/flash, operation of valves, operation of stepper motors for probe and model attitude gear. It is used for input of data from flags, BCD output from transducers. (Ref. Appendix A).

3.10 Analog I/P Interface to pdp 11/03:

This is used to sense the transducer input from pressure probe. It is dealt in Appendix A.

3.11 Multiplex Card for Digital Input:

This card has been fabricated using DM 74157 Quad 2 line to 1 line data selector chip. Thus 4 chips are used to control 16 bit input to DRV 11, from 32 data input lines of temperature probe, flags and scanivalve. Two bits (04 & 05) have been earmarked for the control of this card which will need expansion to 64 to 16 line selector with the inclusion of flag checks for readiness of subassemblies.

It is proposed to introduce (Ref. Fig. 1.3 Appendix A) automatic flag checks for subsystem readiness at a later stage. The flags will be set for all subsystems and one bit will be allotted for each flag to be input to DRV 11 input buffer through multiplexer card. This will replace present man-machine dialogue on servicability. (Also Ref. Fig. 1.4 Appendix A).

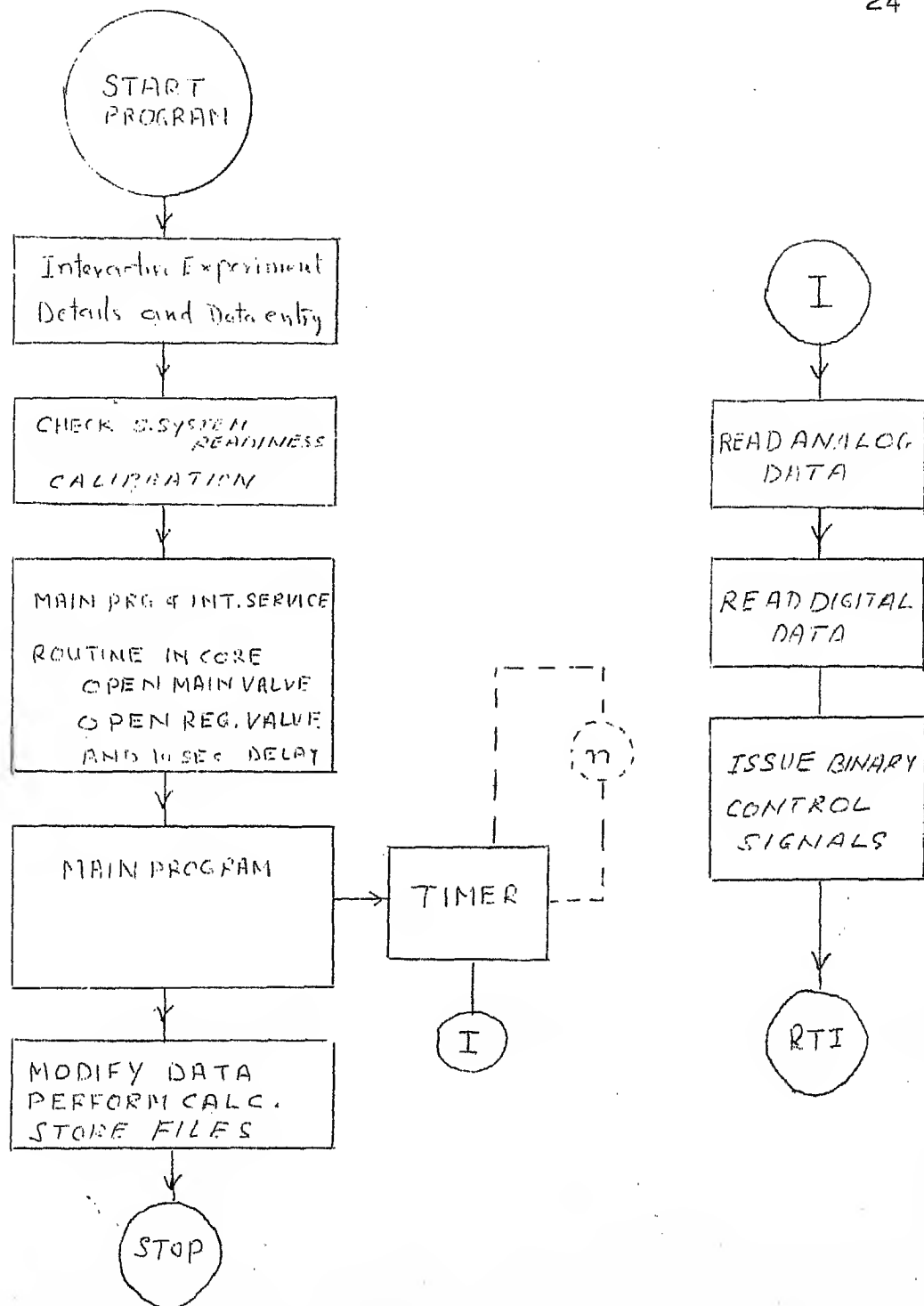


FIG 4.1

4. SOFTWARE DESIGN

The software design is based on the programmable clock event generation capability. The timing event is taken as a reference point to start the sequence of readings and control outputs. After the regulator valve is given control signal to open there is a 10 seconds delay for stablization of flow conditions in tunnel working space. Immediately following this the buffer of the programmable clock is filled with an integer number a multiple of $N1/N2$ (Total time of experiment/number of readings of probe). The clock starts a count down of this number to present the next event for reference. In the mean time 1st set of readings of probe for pressure and temperature are taken and the probe and aircraft model is moved to next position, now the system waits for the time-event interrupt. On occurance of the interrupt the system performs the task of taking readings and issuing control signals if necessary for scanivalve also and the clock buffer is refilled with this integer number which again starts its count-down schedule for the next event. This process is repeated till the required number of readings have been taken. The interrupt routine in principle must be core resident which does the task of reading the probes and issuing control signals for probe and pitch drive

mechanism. Figure 4.1 gives a simplified flow chart of the design. The mainflow chart covering the general characteristics is as per Appendix B, the main features of the flow chart are as follows.

1. Conversation and data entry routine: This routine enters data through console type-writer in the form of man-machine dialogue in question answer form. This has been done with the assumption that the experimenter may not be a computer trained personal. First the date, experiment number, mach number and experimenter's details are entered followed by experiment parameters input of total time of experiment, number of probe readings, no. of snaps to be taken and initial and incremental pitch. These inputs are stored and based on these the programmable clock is driven for event generation and processor to give appropriate reading and control signals (pulse train). This parameter input part may be replaced by automatic check of thumbwheel switch inputs.

2. Sub-system readiness check routine: This routine is also in the form of man machine dialogue to ascertain readiness of all the associated subsystems e.g. DC power supply, scanivalve system, probe and model attitude drive systems, calibration and analog input subsystems, camera and flash

equipment. Provision has also been made to hypass the subsystem not likely to be used in that particular experiment. When the control console is finally designed it is proposed to automate this routine through flag checks. Each subassembly shall give a TTL output to the digital input buffer of the computer (known as flag) which will be automatically scanned for its asserted level. (Ref. Fig. 1.3 Appendix A). Any bit not set will be reported on the console to check if the subsystem is required to be hypassed.

3. Calibration routine: This routine is again in interactive form which outlines the procedure for setting zero offset and calibration. It issues instructions to connect precision reference voltage at the amplifier input to calculate gain for later reference while reading the input through computer A/D converter. This routine also may be automated through the use of relay selectable voltage references for which bits are available on Digital output buffer.

4. System readiness check routine: This routine again checks the system readiness as one unit and issues control signals to bring probe and model to initial position. This is to fix the initial positions for the first set of readings.

5. Start routine: This routine gives the control signal to the main valve to open its port and checks for its full open sense flag. When the full open sense flag is set it issues control signals to switch on the regulator, valve, thereafter it starts the clock to count for 10 seconds to give stabilization delay. On expiry of the 10 seconds delay period the programmable clock is instructed to start its count schedule while the set of readings and control signals to fix the new positions are issued.

6. Traverse gear control routine: This routine derives its input in the form of number of steps to be moved/reading (number of steps = $200/\text{Number of total probe readings to be taken}$). The routine generates through software a sequence of pulses for the required number of steps to be moved along with direction control (bit asserted zero for forward and 1 for reverse direction). The output of sequence of pulses and direction control is given to the stepper motor controller hardware.

7. Model attitude control gear routine: This routine is similar to number 6 above. It derives its control parameters of initial and incremental pitch through conversation routine. The task of this routine is to align the test model to the required attitude as defined in experimental parameters.

8. Analog data input routine: This routine defines the analog input channel number and the variable to which the collected data must be assigned. The routine takes the analog input from the pressure probe and stores it for future reference.

9. Programmable clock routine: The input to the routine is defined by the duration of the experiment and number of maximum probe readings to be taken. The clock buffer is filled by an integer number proportional to the time event and crystal frequency. The clock generates an interrupt when the count down is over. It is either called by itself through the routine or fills up the buffer again and starts the count down schedule by itself for next event. In case of IBM 1800 the timer calls itself while in case of pdp 11/03 this is automatically done by mode selection.

10. Camera/flash routine: This routine determines the requirement for camera/flash operation as defined by experimental parameters. It checks the counter flag for its turn and issues required control signal for the activation of camera and flash through digital output buffer through two bits allotted for this purpose. The camera operation needs a pulse of 100 ms width and the flash of 10 ms width which are software generated. The camera takes a snap & moves the film to next frame for exposure.

11. Scanivalve routine: This routine checks for the time event when a control signal must be issued to lock the ports. Once the ports are locked this routine is called again after the experiment is over to collect the BCD data from the ports and store the same in the array.

12. Temperature routine: This routine checks the time event for taking the temperature reading. It issues a temperature hold command and takes the probe reading and then clears the hold so that the module can sense the new temperature. The data in BCD format is kept in an array.

13. Data correction routine: Here the collected BCD data from the arrays of pressure and temperature probe are taken and converted to correct decimal value for storage. The IBM-1800 DACS is discussed in Chapter 5. The pdp 11/03 DACS is discussed in Chapter 6. Both the software implementations are dependent on the above logic.

5. IMPLEMENTATION DETAILS IBM-1800

This chapter describes details of IBM-1800 TSX operating system and DACS implementation details which were used to demonstrate the feasibility of the concept.

5.1 IBM-1800 Time Sharing Executive System (TSX) (Ref. 1800-36-pp 1-2):

Real time applications have two chief characteristics (i) continued on line communication with some external process (ii) necessity to keep pace with associated process in operation. The TSX operating system takes care of these two problems. It acquires data from both on line and off line tasks with the help of foreground and background environment operation. It has essentially two parts

- i) Skeleton executive
- ii) non process monitor

The skeleton executive process control and data acquisition application are serviced in the on-line mode while the non-process monitor operates in time shared/independent off line mode. The background job is done when foreground relinquishes control. The minimum configuration for TSX is a processor with at least 8K primary memory, secondary disk memory, keyboard and CR.

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5.1.1 Modes of operation: (Ref. 1800-36- pn 37)

In a real time process the computer must rapidly respond to the signals by conveying some output to the process. TSX in this mode operates under skeleton executive. Here the operation can be monitored/controlled by user written program. The process may be shared between process and non-process work. All core loads/programs are accessed from system resident disk pack. In the off line mode the TSX operates under TASK (temporary assembled skeleton) as dedicated N.P. monitor system. Typical OFF line applications are assemblies, compilation, utility function etc.

5.2 System concept: (Ref. 1800-36 pn 3 to 26)

Skeleton executive is the back bone of the system. It is core resident for real time while other portions of the system are swapped from the diskas and when required. (For memory map ref. Fig. 5.1).

Program segementation known as core load is used to extend use of limited core memory. The skeleton executive on core is devided as follows:

1. Skeleton I/O
2. Inskel common common area in skeleton for communication among various types of core load used in the system.

3. System Director It directs handling of interrupts, supervises main line core loads execution of programs, services error condition, maintaining interval time & NP monitor.
4. User Written Programs Frequently used SRS e.g. interrupt service routine, time counts etc.

5.3 Interrupt Handling:

It consists of hardware priority structure, core store data area for each interrupt level and master interrupt control program (MIC) to recognise the source of interrupt and direct its servicing. There are 3 fixed and 24 additional sources of interrupt levels assignable by the user. Each interrupt line is positioned into a table of priority. Request line is activated if no higher priority interrupt servicing is done else it is queued. A unique address associated with the interrupt level is supplied to the system to locate its service routine. For quick service the routine must be included in skeleton at sys. gen. time. The reason that the feasibility could not ^{be} limited to 20 sec. time limit was that the interrupt service routine could not be included in skeleton as due to inability to do sys. gen. for want of the punch unit.

5.4 Interval timers: (Ref. IBM 1800-36 pp. 42-46).

These are used for periodic scheduling to generate I/O events. The counter is loaded with an integer number and a program controlled countdown to zero is initiated which gives an interrupt which can be used to initiate digital I/O, analog I/O, relay actuation etc.

5.4 Basic concept of DACS in IBM-1800:

The hardware details and configuration of IBM-1800 DACs is given in Fig. 5.3. Each of the functions of digital I/O, Analog I/O in the DACs is implemented by some disk/core resident program. In general there is two way data flow across the process and computer interface through process I/O hardware which significantly affects the software requirements. Most important is analog I/O requiring relay and multiplex devices coupled with multichannel priority interrupt system.

5.4.1 Analog Process I/O:

A/D converters are used to convert the resultant analog signal for computer entry to equivalent digital value. A multiplexer is used to scan different channels. Similarly D/A conversion is done vice versa to control the analog devices. Thus A/D and D/A converter give a digital computer ability to communicate with process signals and control equipment.

LOW CORE

HIGH CORE

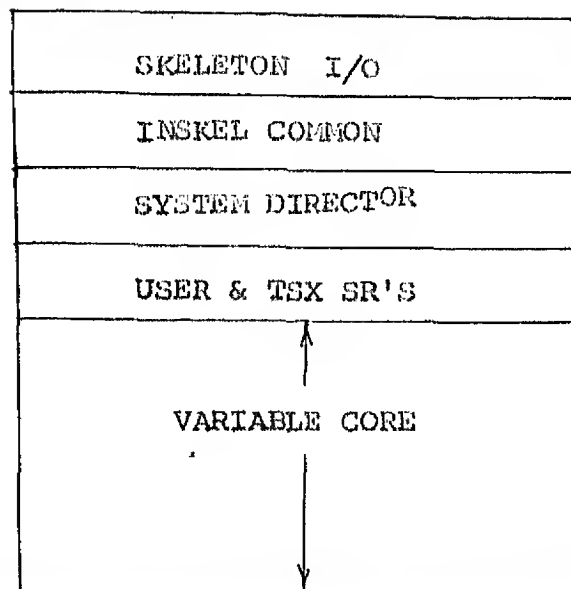


FIG 5.1 MEMORY MAP(SKELETON EXECUTIVE)

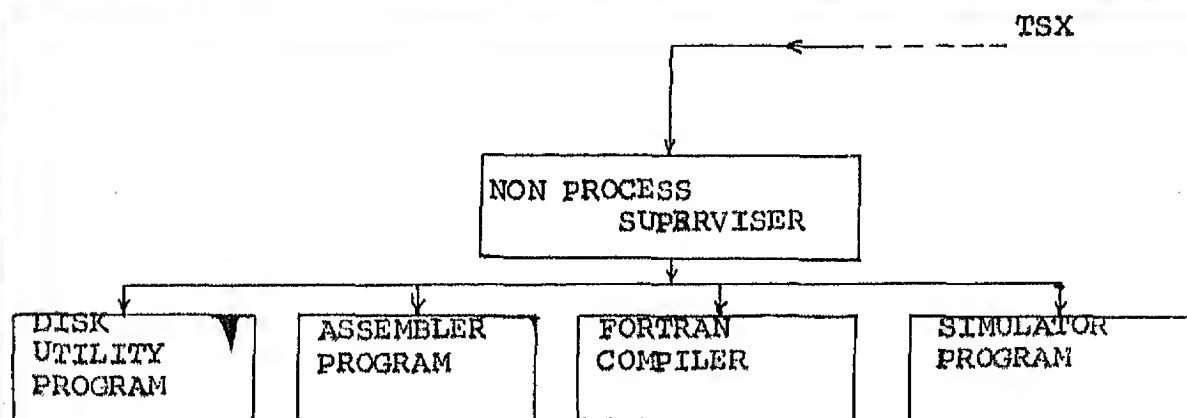


FIG. 5.2 NON PROCESS MONITOR

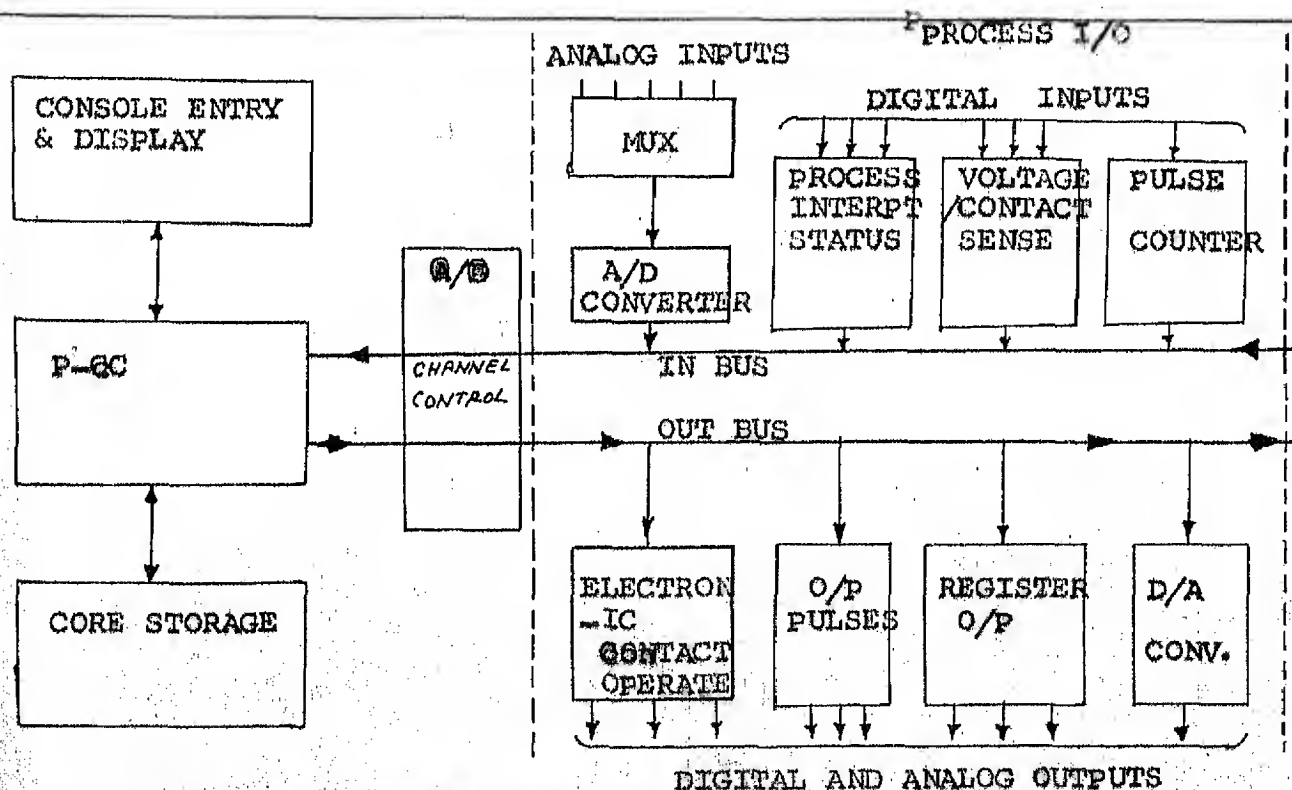


FIG. 5.3 IBM 1800 DACS CONFIGURATION

5.4.2 Digital Process I/O:

These are used for digital signals to control relay operation, give a sequence of pulsed outputs, check flags, input digital data/output digital data to the controlled process. 1800 also provides contact sense and level sense. A process interrupt is like a voltage sense. Digital data can also be read under program control and moved to assigned area by cycle steal.

5.5 Software details:

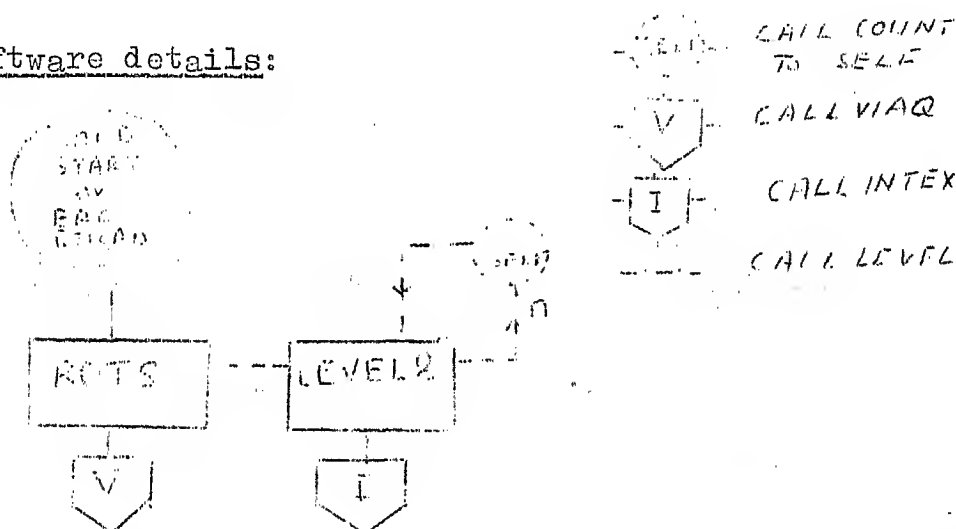


FIG 54

Wind tunnel control and data acquisition concept feasibility was demonstrated on IBM-1800 with software written in Fortran IV. The Fortran program is given in Appendix C which is based on general flow chart of Appendix B.

The main program "ROTS" is loaded in to the core by cold start or EAC (Error alert control). ROTS defines initial parameters of the duration of the experiment, number of probe readings and camera snaps. It also defines Table values for pulse output to drive the stepper motors and camera mechanism. It does the task of unmasking, calibration and timer setting. The timer calls "level 8 routine through "Gen" to execute the interrupt routine. Thereafter the timer calls itself to maintain the periodicity till the required number of readings are over when it relinquishes control to main line core load through call INTEX. In the routine certain parameters were assumed e.g. number of readings to be taken from probe. Hence the timing of 20 seconds was not imposed due to problem of sys. gen. The total experiment took 52.4 seconds. The same could be done in 20 seconds by storing the interrupt routine in skeleton. The experiment is dependent on periodic scheduler, to take readings and issue control signals at defined events. The main routines are as follows.

5.5.1 Main Routine "ROTS":

This is the main line core load routine. It reserves common areas for array, flags and counters used by main line core load. It defines files for I/O to reserve space in the

disk. It defines initial table values for digital output/relay output routines of probe and model attitude gear and camera. It does unmasking through call UNMK and uses conversation subroutine, Delay, Calibration and pitch subroutines. It does initialization of all tables and sets probe and model attitude to initial value. It gives 10 seconds delay to regulator valve for stabilization before the start of the experiment. It starts the clock to note execution times. It starts timer to start count down for event interrupt. This is followed by call VIAQ the last statement of a core load.

5.5.2 Subroutine

This is the initial conversation routine to feed experimental parameters interactively. This also accesses the subsystem readiness before the experiment commencement.

5.5.3 Subroutine Delay:

This subroutine is used to give required delay for the pulse outputs e.g. 9 & 3 ms for stepper motors and 100 & 10 ms. for camera and flash equipment. The subroutine also gives required number of pulses for the steps to be moved along with the direction control. The do parameters were used to establish the correct pulse widths for smooth operation of the stepper motors. (M & N are the array parameters).

5.5.4 Subroutine "Gen":

The skeleton contains a timer subroutine for timer 1 which is called by system subroutine call timer, which is given either number 1 or 2 depending on A or B timer. An integer number represents the count value in the counter. When the count is over this SR Gen. is called which calls level 8 interrupt core load which is disk resident in core image format.

5.5.5 Subroutine PIT:

This subroutine does the task of generating the required pulse train for the control of the stepper motor driving the model attitude gear to change the pitch of the aeromodel. It sets the table contents of IDATA and then calls system SR of DO to set the required bit pattern in digital output register. It uses delay SR to give the pulse right width.

5.5.6 Subroutine Cal:

This SR is used for calibration of the amplifier and setting its zero offset. This intturn calls AIP subroutine to define input channel number of the variable where data can be stored. The calibration is done through interactive dialogue. It then stores the gain for future reference.

5.5.7 Level 8 Interrupt core Load "ROTSS":

The interrupt core load "ROTSS" is called through subroutine Gen. on expiry of the timer count. This interrupt core load program is kept in the disk in core image format for quick loading. It uses common areas reserved for communication by "ROTS". It calls system SR DO to communicate to stepper motor drive system of pitch control by using the table values IPOSE, the table values are modified as determined by experiment parameters. Delay SR is used for pulse width control. The probe analog readings are taken through AIP subroutine leaving the value in a variable. The camera and flash are operated through contact operate again by defining table values of IKAM. If the required number of readings is not over the timer is again called to start count, on completion it hands over the control to main line core load through call INTEX.

6. IMPLEMENTATION DETAILS OF PDP 11/03

This chapter describes the real time operating system of PDP 11/03 called RT-11 and the implementation details of software.

6.1 RT-11 Operating System:

RT-11 is a disk based single user real time operating system designed for interactive program development and/or online application on PDP 11/03 series of DEC. It supports both single job (SJ) and foreground background (FB) modes of processing. In addition it does a variety of system and program development utilities. It also supports Fortran IV, Basic, Focal and APL higher level languages. It is a device independent system giving full monitor services e.g. file management, control of system operating characteristics, integration of system state and resources and interrupt servicing. It offers special advantage in lab application purposes. The I/O system has device handlers as files on system device.

6.2 Monitor Orginasion:

The optional two monitors of SJ and FB can be used to users advantage. The FB monitor allows two programs to operate simultaneously one in the foreground and another

in the background. The foreground job has priority over system resources. Functions which do not need time critical requirements can be developed in the background. Both the monitors have access to system resources. Both can communicate to each other through disk. FB require 4.2K words of core space. The SJ operation needs only 2K words of core. In our application only SJ monitor has been used as ^{simultaneous} processing requirement is not there.

RT-11 monitor is modular in nature so that only these portions actually in use at a given time are core resident. The monitor has 4 major modules plus the device handlers needed for the configuration. Modules are as follows.

- (1) RMON (Resident Monitor):- This is the only permanently core resident module occupying 2K words for SJ & 4.2K words for FB in core. It resides at the top of memory. It handles all programmed requests for RT-11 services.
- (2) KMON (Keyboard Monitor):- It provides interactive facility between console^{and} RT-11. Monitor commands allow the user to assign logical names to devices, run programs, load device handlers and control F/B operations. A dot printed by monitor on console is an indication of KB monitors presence. It is swappable and takes 2K words of memory.

- (3) **USR (User Service Routines)**:- It provides support for RT-11 file structure. It loads device handlers, opens files for read or write operation, deletes and renames files and creates new files, CSI (command string interpreter) is actually a part of this which can be accessed by any program to interpret a characterizing It takes 2K words of memory.
- (4) **DH (Device Handlers)**:- These are short routines. These are merely files on the system device which can be easily created by the normal editing and assembling process. In our system for wind tunnel only the device handler of Floppy disk (216 words) and console terminal LA36 (140 words) have been included. These are swappable.

6.3 General Memory Layout: (Ref. Fig. 6.1 and 6.2)

The above diagrams give the initial memory layout of RT-11 on boot strap, it consists of RMON, USR and KMON but when device handlers are loaded they take place between RMON and USR pushing USR and KMON down. RT-11 maintains free memory list to manage memory layout. In SJ, RT-11 allows the program to be loaded over the KMON and USR if it exceeds the free memory available. When the program is running the

777777
760000

(EXTERNAL MEMORY) DEVICE REGISTERS	
<u>RMON SJ (1.6K):</u> DT, I/O QUEING, USRSWAP R/W PROCESSOR, TTY INT, MON, FUN, EMT, SYS I/O TABLES	
<u>USR (2K) SWAPPABLE:</u> - CSE, USR TABLES USR, ERROR HANDLER	
<u>KMON 1.5K SWAPPABLE:</u> - K.B. FUN COMMAND DISPATCHER, KMON OVERLAY KMON, USR SLIDE ROUTINE	
USER SPACE (CONV. ROUTINE SWAPPABLE) REST CORE RESIDENT	
USER ↓ STACK	377 360
SYS. CORE CONTROL BLOCK	357
DEVICE INT. VECTORS	60
SYS COMMON AREA	57
HARDWARE/SOFTWARE TRAP VECTORS	40 37 0

Fig. 6.1 RT-11 SJ MEMORY LAYOUT

SAME AS SJ	
<u>RMON 2B (3.3K):</u> - DT, JOB SWITCHING, COM INT, CLK. INT, QUEING, MSG. HD W/R ROUTS, MON. FUNS, EMT. PROC. EMT ERROR BACK G.I. AREA SYS TABS.	
FORE GROUND AREA (EXP ROUTINES) CONV. ROUTINE SWAPPABLE	
<u>USR (2K) SWAPPABLE:</u> - SAME AS SJ FILE ORIENTED FUNS	
<u>KMON (1.5K) SWAPPABLE</u> SAME AS SJ MONITOR	
BACK GROUND AREA (CALCULATION/COMP. ROUTINE) OF EXP.	490
SYS. CORE CONT BLOCK	372
DEVICE INT VECTORS	360
SYS COMMON AREA	357
HARDWARE/SOFTWARE TRAP VECTORS	60 57 40 37 0

Fig. 6.2 RT-11-FB MEMORY LAYOUT

USR and KMON are not core resident and if required part of the program is swapped out to make room for USR which is again swapped out when not required. KMON & USR remain core resident if enough memory for the program is available.

6.4 Commands :

The operator controls and directs system operation through three different interfaces. Operator communicates directly with the monitor using KB commands and special function keys, communicates indirectly with the monitor or user programs by issuing an I/O command string. Keyboard commands and special function keys allow the operator to instruct RT-11 monitor to allocate system resources, manipulate memory images, start program and use foreground/background services. RT-11 monitor provides services for program initialization, control of system operating characteristics, interrogation of system status and resources, command interpretation, file operation, I/O transfer, program transfers and interrupt servicing. Special features are clock operation, timed wait etc. All I/O is handled in a block format directly to and from the user area without intermediate buffering. The queue manager processes all I/O requests in a normal way. Each device has a queue. The I/O is done in three modes: synchronous, asynchronous and event driven.

6.5 Timer Support:

With the macro, `.MICTIM` request the user specified address of a routine is extended for execution after a specified number of clock ticks. These routines are asynchronous like I/O routines, independent of main program. After the specified time elapses the main program is interrupted, the time completion routine executes and returns control to interrupt program. `WAIT (0)` is used to wait for interrupt occurrence.

6.6 Interrupt Service :

Hardware is eliminated by the use of two program requests for service of interrupt routines to provide necessary link to the monitor I/O system. It allows the use of system stack for interrupt service and allows scheduler to make note of the interrupt. The rest interrupt principle is the same as for IBM-1800. RT 11 provides a set of system programs for macro, edit, expand, assemble, lines, odt, PIP and other utilities. It also provides call and link of an assembly routine through basic `Call` statement. Extensive use has been made of this facility in this thesis for control and data request statements.

6.7 Software implementation in PDP 11/03

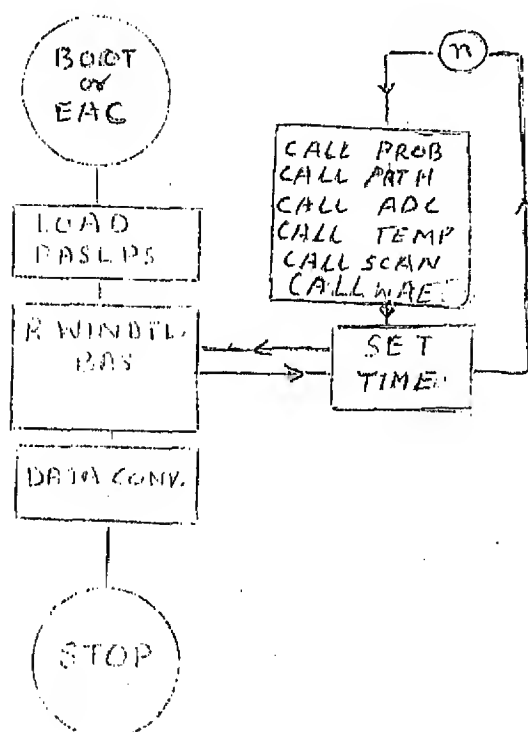


FIG 6.3.

The software implementation in PDP 11/03 follows the above logic which is dependent on general software design as per Chapter 4. The program is dependent on a periodic scheduler. The basic program is based on the flow chart of Appendix B where only one dimensional control of probe and pitch has been implemented. The necessity of feedback closed loop control has not been felt due to precise control available on stepper motor positioning. Initially when the PDP 11/03 is booted the resident monitor is brought to the core, then BASLPS /OS is loaded to run the basic WINDTL

BAS experiment program. The experiment is started with a RUN command. The Basic program for control and data acquisition includes the assembly language routines written for control of various parameters linked in BASLPS which can be called by a CALL statement in users program.

6.8 WINDTL.BAS main program: (Ref. Appendix D for program)

The program has been written is basic so that there is no need to have skilled computer personal to run/modify the program. Statement No. 5 to 160 are the routines meant for interactive operation for input of date, experiment number, mach number and experimenter's name. These are stored.. Statement No. 170 to 340 deal with the input of the experiment parameters of duration of the experiment, number of probe and temperature readings, number of camera shots, initial and incremental pitch. These are again interactively entered through Decwriter console in question answer form. Statement No. 360 to 365 deal with the readiness of subassemblies associated with the experiment. This is also done in question answer form. Provision has been done to bypass the check of subassembly not required for a particular experiment. After the installation this part of the routine will be replaced by automatic flag check routine

for which hardware interface is given in Fig. 6.3. Two bits to operate MUX. cct. have been reserved, out of which only one is being used for this routine.

Statement No. 870 to 1040 does the job of calibration of the amplifier utilized for the pressure transducer probe. The calibration is done through question answer routines where connections are made manually to connect reference voltages this will finally be replaced by relay operation routine to do the task automatically only zero offset will have to be manually set. ADC routine is used to collect data and gain G is stored for future reference.

Statement No. 1060 to 1200 checks the final readiness of the system so that no parameter is by mistake off. Calculation for this integer value of counter buffer, value of flags and steps for motors are assigned here.

Statement No. 1300 to 1400 issue the necessary control signal for the initial position setting of the model attitude and probe through CALL "PITCH" and CALL "PROB". Now the environment for the initial settings of the experiment is set to go ahead with the opening of the valves for air flow.

Statement No. 1600 - 4300 cover the main experiment operation. First the main valve is issued control signal to open the port and its full open indication flag is sensed before command to

open the regulator valve is issued followed by 10 seconds delay. This is achieved by CALL "VALV" statement No. 1700 and CALL "SETC" of statement No. 1800. Statement No. 2050 i.e. CALL "SETR" starts the clock to give time event indication determined by experimental parameters N1 & N2.

Statement No. 2300-2350 take the pressure probe reading from channel zero and store the result in the array at A1 through CALL "ADC".

Statement No. 2400-2500 take the temperature probe reading through CALL "TEMP" and store the result in an array A2.

Statement No. 2600-3000 control the camera/flash operation through CALL "CAMR". These determine how many times the camera must be operated during the experiment as defined by initial parameters.

Statement No. 3200 to 4100 control the operation of the stepper motors controlling probe & model attitude gear through CALL "PROB" and CALL "PITH". Here command is also issued at appropriate event for the operation of scanivalve through CALL "SCAN".

Statement No. 4200 makes the process wait for next time event to occur to repeat the process.

Statement No. 4400 to 6000 collect the data from the 48 ports of the scanivalve through CALL "SCAN" and store the same in Array A3. Now the data in 4 bit BCD format is again called from the array and corrected to correct decimal format and stored back in the array A3.

Statement No. 6025 to 7200 do the conversion of the 4 bit BCD data in to decimal, stored in array A2 from temperature sensing module. The corrected value is stored back in array A2.

Statement No. 7300 to 8200 are normal output routines for data in the arrays and the character strings stored for experiment details.

The various CALL statements used in the program are as follows:

CALL "ADC (A,C):- This is a system routine in module 1 to take analog readings. This command initiates the activation of the specified channel A its analog sample taken and return the digital value in the variable C.

CALL "TEMP"(C) : This routine has been written in assembly language (Ref. Appendix D). It initiates the collection of the binary data available to the input of DRINBUF from the temperature

module by giving a hold signal to it through bit 09 of OUTBUF of DRV-11. In the routine the syntax and arguments are also tested. The final collected value is kept in variable C. Now the hold bit is cleared so that the temperature module could proceed ahead for next reading, DRINBUF=167774, DROUTBUF = 167772.

CALL "VALV" :- This assembly language routine (Ref. Appendix D) had been written for the automation of two valves. First it switches on main valve by setting the bit 12 of DROUTBUF. It now checks for complete open indication through bit 7 of DRCSR, when the same is set, issues command to open the regulator valve by setting bit 13 of DROUTBUF.

CALL "CAMR" :- This assembly language routine (Ref. Appendix D) has been written to operate the camera and flash equipment for photography. The camera is operated by setting bit No. 15 of DROUTBUF for a required width of 100 ms. and the flash through setting of bit No. 14.

CALL "PITH" (A,B): This assembly language routine (Ref. Appendix D) controls the operation of the stepper motor controlled model attitude control gear assembly. The routine checks the syntax and arguments through Getarg. A is the number of steps to be moved and B is the directional control parameter. Since arguments A&B are stored in two words each this is packed in one word and moved to Reg. R2 & R3. The routine introduces the proper width of the pulse i.e. 9 ms followed by a 3 ms gap between two pulses. The routine for each grid point is called only once which generates complete pulse train. (B is zero for forward and 1 for reverse direction).

CALL "PROB" (A,B): This assembly language routine (Ref. Appendix D) control the operation of the stepper motor controlling the linear movement of the pressure transducer probe in the tunnel working space. The routine is similar in all the respects to CALL "PITH".

CALL "SCAN"(A,C): This assembly language routine (Ref. Appendix D) controls the operation of the scanivalve system. First the syntax and arguments are checked through Getarg. A gives an indication of the control for locking the ports (A=1) or for data acquisition (A=0) in the relevant cases bit 12 & 11 is set for operation. The value in the later case is stored in variable C. This routine will need modification to include hold command while data is being acquired, this detail could not be included due to lack of technical details on scanivalve.

CALL "SETC"(Time,rate): This is a system routine in module 2: This controls the operation of programmable clock the argument time and rate is to be specified. The clock status register is set to rate and will run for time seconds. On expiry of it a clock interrupt will occur to do any of the clock controlled function. The time argument is calculated a $TIME = \text{time in seconds} \times \text{clock rate specified}$.

the clock is run in zero mode for non repetition (Ref. PPI-8 of Basic RT-11 manual).

CALL "SETR"(Rate, mode, preset): This system routine governs the programmable clock by setting the clock running in specified mode and at desired rate. The preset is clock counter value. The interrupt enable is always set. The rate values are from 0 to 7 defining clock rates of no rate, 1 MHz, 100 KHz, 10 KHz, 1 KHz, 100 Hz, schmitttrigger & line frequency respectively. We have taken this as 2 (i.e. 100 KHz), Mode value 0 to three define simple interval mode, repeated interval mode, external event mode and event timings. We are using mode 0. The buffer preset value has been calculated as $T = \frac{N1}{N2} \times 100000$ (Ref. pp I-8 of Basic RT manual).

CALL "WAIT" (N): This system routine disables further program execution until the specified event "N" occurs, n=0 for clock over flow, n=1 for schmitt trigger, n=2 for either of them to take place.

The use of Getarg is done for syntax and arguments check of the CALL statement, the STORE SR keeps the value of register in the variable C. FAC1 & FAC2 are Table addresses while OUBF, INBF & DRCSR are the DR11 - OUTPUT BUFFER (Address 167772), INPUTBUFFER (Address 167774) and control and state register (Address 167770) respectively. The above assembly routine of Appendix D were assembled as FUN4.MAC and the function table was assembled as FUN3.MAC. FUN3.MAC was amalgamated into the RT11 function table FTBL.MAC to include the other routines. Finally ROTS2, was produced by linking all module as per following procedure.

```
. R MACRO
* FTBL = PERPAR, FTBL
* PERVEC= PERPAR, PERVEC
* RTINT = PERPAR, RTINT
*
. R LINK
* ROTS2=BASICR, FPMP, FTBL1, PERVEC, RTINT, GETARG/C
* FUN4, BASICE, BASICX, LPS0, LPS1, LPS2C, LPS3, LPS4,
  BASICH.
```

ROTS2 has been loaded as BASLPS.SAV in the floppy disk. This operating system along with WINDTL.BAS, FUN3.MAC & FUN4.MAC has been copied in a floppy disk (details in Appendix E). The disk has been given to the users ready to be loaded on arrival of the system.

7. CONCLUSION

A Digital Controller and Data Acquisition System has been designed for implementation on trisonic wind tunnel system of Aero. Engg. Dept. of I.I.T. Kanpur. The system which is based on DEC micro-computer PDP 11/03 provides complete control of the wind tunnel i.e. operating of main and regulator valve, movement of pressure transducer probe and change of model attitude through attitude control gear, control of scanivalve and temperature sense module. The system acquires data from temperature and scanivalve multiplex system in BCD format and from pressure transducer in analog form. The computer based control and data acquisition system now makes it possible to take complete set of readings on a test model in one experiment itself while exercising precise control on movements thereby eliminating human errors. So far the data acquisition and control was exercised manually therefore it was possible to have few observations only in the 20 seconds duration. The feasibility of the software was first tested on IBM-1800 with successful control of all parameters. The PDP 11/03 routines have been tested for correctness at MOD Delhi computer. The modified RT-11 includes all additional call routines for wind tunnel control. The routines have been transferred to a floppy disk ready to run.

7.1 Future Additions:

The CALL routines have been kept simple & flexible to include more features if required. Since scanivalve technical details were not available the CALL "SCAN" routines will need modification to include more details for hold and other control signals. These extra routines can be added to FUN4.MAC before being included to FTBL. The main program has been written in Basic so that any one can run & modify the program with insertion of new statement numbers. Although the requirement of Aero. Engg. was to take maximum 40 readings of probe during 20 second experiment it can be easily take up to 400 readings in 20 seconds duration without change of hardware with little modification of software with parallel movement control of two stepper motors. With modification of hardware upto 2000 readings can be easily taken during this period. Thus enough flexibility is available. Once the control console is finalised the whole operation can be automated as suggested in the thesis thus the operator need not do any thing than the initial conversation. (Ref. Fig. 1.3 and 1.4 of Appendix A).

APPENDIX A

HARDWARE DESCRIPTION OF PDP 11/03 IN BRIEF

Configuration: (Ref. Fig. 1.1). The PDP 11/03 JB system consists of LSI 11/03 microcomputer with 32 K bytes of MOS memory, extended arithmetic set and option given in the proposal of Chapter 2. The KD 11-F Microcomputer module includes all function chips e.g. processor data chip, processor microinstruction ROM chip, processor control chip, bus drivers and receivers, bus I/O control logic, interrupt control and reset logic, bus arbitration logic and special function. The clock pulse generator generates 4 non overlapping clocks for different functions. It has 402 instructions and is fully compatible to other DEC series. It has 16 K x 16 bit dynamic MOS memory which requires refresh operation every 1.6 ms. which is automatically done. Access time is 300 n.s. DLV 11- Asynchronous Line Interface connects bus to several communication lines. This module receives serial data from peripheral devices, assembles it to parallel data and transfer it to LSI-11 bus. It performs function vice-versa for data from LSI-11 bus to peripheral devices. It can give Baud rates of 50 to 9600.

DRV11-Parallel Line Unit: This is a general purpose interface unit for controlling TTL-DTL devices connected to LSI Bus.

It can support up to 25 feet of cable thus giving us enough length to carry cables upto control console. It offers program controlled data transfer at rates up to 44 K words/second. Data is handled by 16 diode clamped input lines and 16 latched output lines. Device address is selectable. In our configuration this module controls operation of probe and model attitude control stepper, motors operation of relays to operate main & isolator valve, control of multiplex selector of input lines, operation of camera and flash units and operation and control of scanivalve system and temperature sensing module. It also accepts inputs from temperature sensing module and scanivalve pressure sense multiplex system in 4 bit BCD format. The interfacing to user devices is done through burg connectors. Its output interface is a 16 bit buffer DROUTBUF which can be either loaded or read under program control. Loading of OUTBUF also generates a New Data Ready 300 n.s. pulse which will be utilized for scanivalve data collection at a later stage. The input data interface is also 16 bit called DRINFUF which comprises of gated bus drivers that transfer data from user devices on to the LSI-11 bus under program control. DRINBUF is not capable of storing data. When data has been read it generates a +ve going Data Transmitted H pulse to inform the user device that the data has been accepted.

Two request flags Req. A&B can be accessed by user device in DRCSR word. In the CALL "VALV" routine REQ A has been used to sense the full open valve condition of main valve thus saving a bit in DRINBUF. (Ref. Fig. 1.2 for bit allotment and Digital EK-ADV11-OP-002 for details)

ADV11-A Analog To Digital Converter: This is a 12 bit successive - approximation A To D converter with built in multiplexer and sample and hold for use on the LSI-11 bus. It has provision for 16 channel single ended input or 8 channel differential input. A to D conversion is either program controlled or clock over flow controlled or external event controlled, as determined by its control and status register (CSR). Digital A/D conversion data is routed through a buffer register to LSI-11 for programmed transfer to memory. It has also the precision output voltage for user test purposes. It is proposed to use this as reference voltage for calibration of amplifiers. Analog input scale range is 10.24 V. Bipolar (-5.12V to +5.12V). The gain and offset error is adjustable to zero. It works in following steps.

1. Enable specified channel
2. Sample the channel
3. Performs A/D conversion
4. Hold the sample
5. when LSB has resolved in successive approximation register (SAR), it transfers SAR contents to Data buffer.

6. Inform process that the job is done
7. Reacquire and Track the programmed channel.

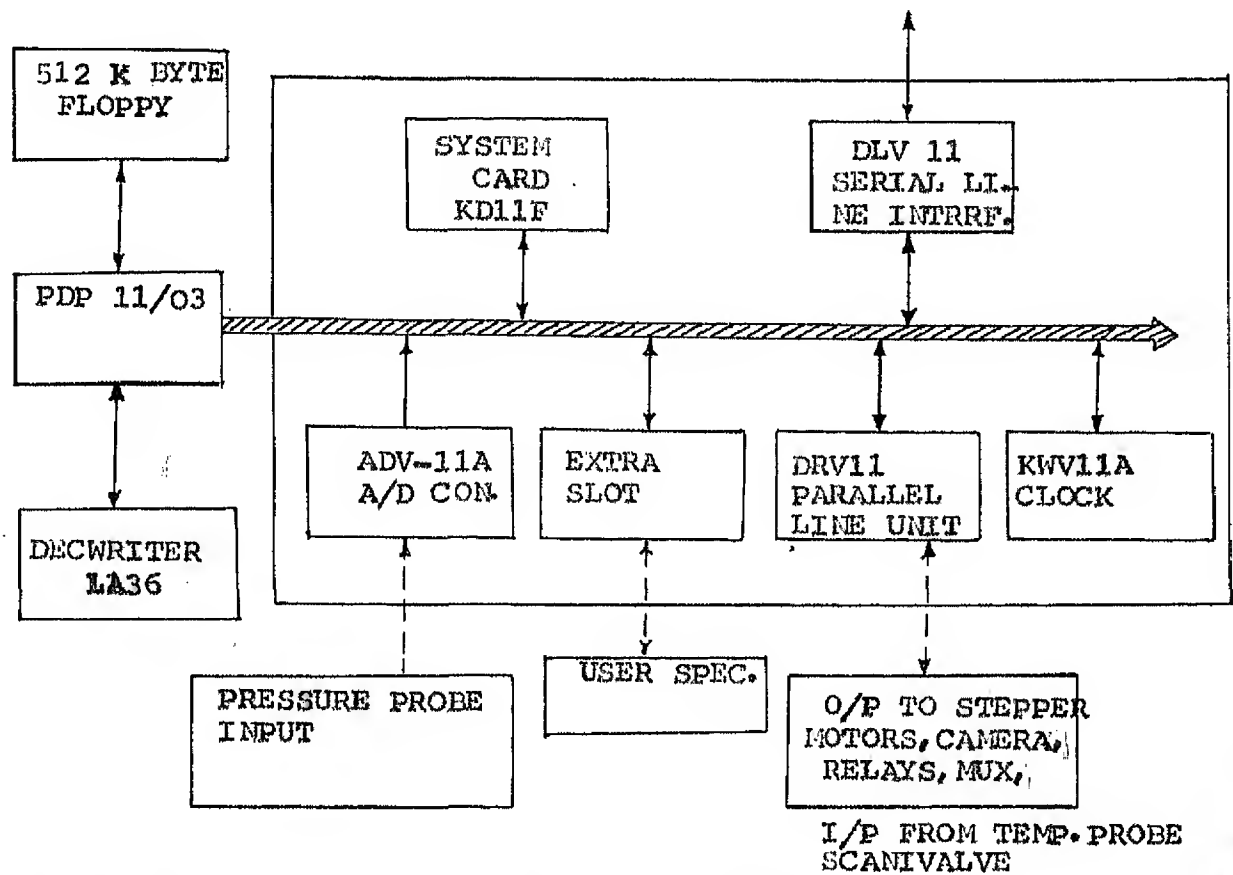
In our system it is being used to acquire data from pressure probe.

AAV-11-A Digital to Analog Converter: This is 4 channel D/A converter module for LSI. It has interface circuitry, 4 D/A converters and voltage references. It has 12 bits of resolution each channel has its holding register which can be separately addressed. Bit 0-3 of 4th holding register can be used as 4 bit digital output register. The analog output range is $\pm 2.5V$ to $\pm 10.24V$ bipolar 0 to 5.12 V or 0 to 10.24 V unipolar, drive capability ± 4 mA per converter, slewing speed $5V/\mu s$. Originally this module was planned to drive the model attitude control motor which has now been replaced by stepper motor for accurate control. Its 4 bit digital output can now be utilized to drive relays.

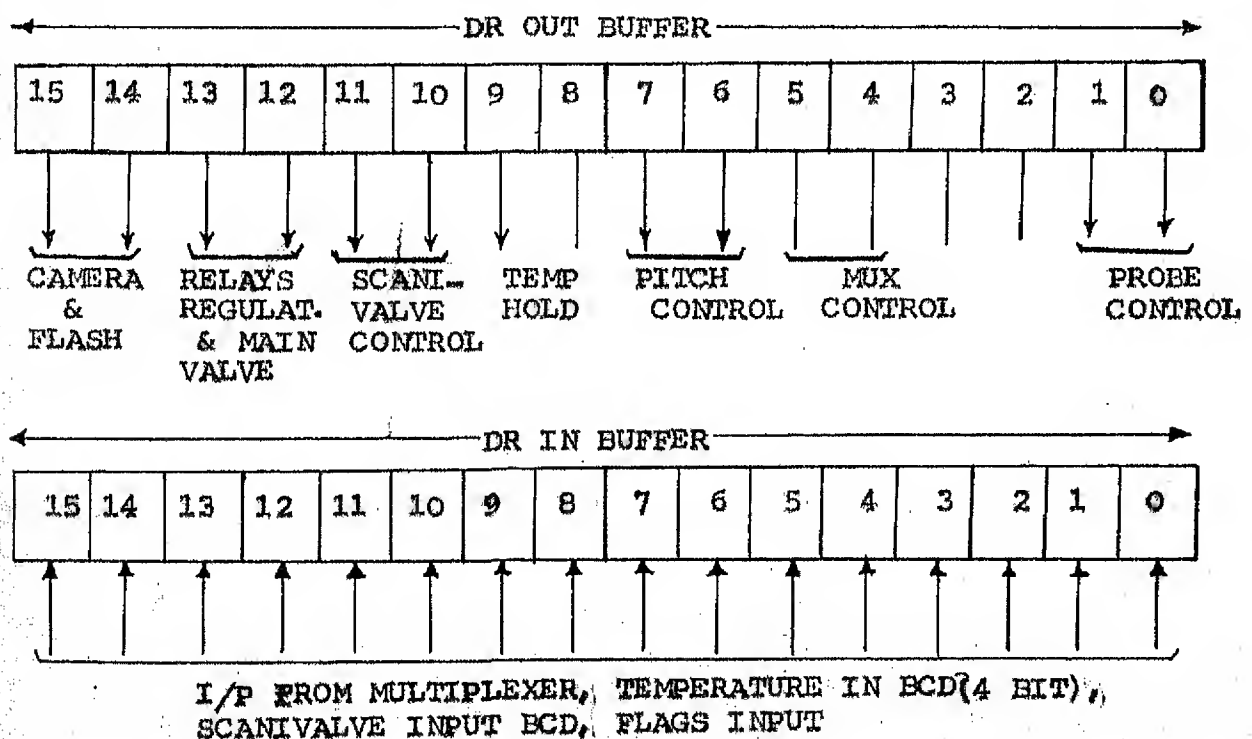
KWV-11A Programmable Real-Time Clock: This is a programmable real time clock/counter combination providing a variety of means for determining time intervals or counting events. It can be used to generate interrupts to LSI-11 processor at predetermined-intervals, to synchronise processor to external events. It can also initiate A/D conversion. It has a 16 bit resolution and it can be driven by any of the

5 crystal controlled frequencies (100 Hz to 1 MHz) or line frequency/schmitt trigger. It has 4 programmable modes. The clock over-flow pulse is 500 ns. wide. Its CSR provides a means for the processor to control the operation of KWV11-A and to derive information about its operating condition. Bits are provided for enabling interrupts, mode selection, maintenance operation; start of counts and overflow and Schmitt Trigger event monitoring. Buffer/preset and counter register is 16 bit read/write register which can be loaded either under program control or from the counter as per the mode of operation.

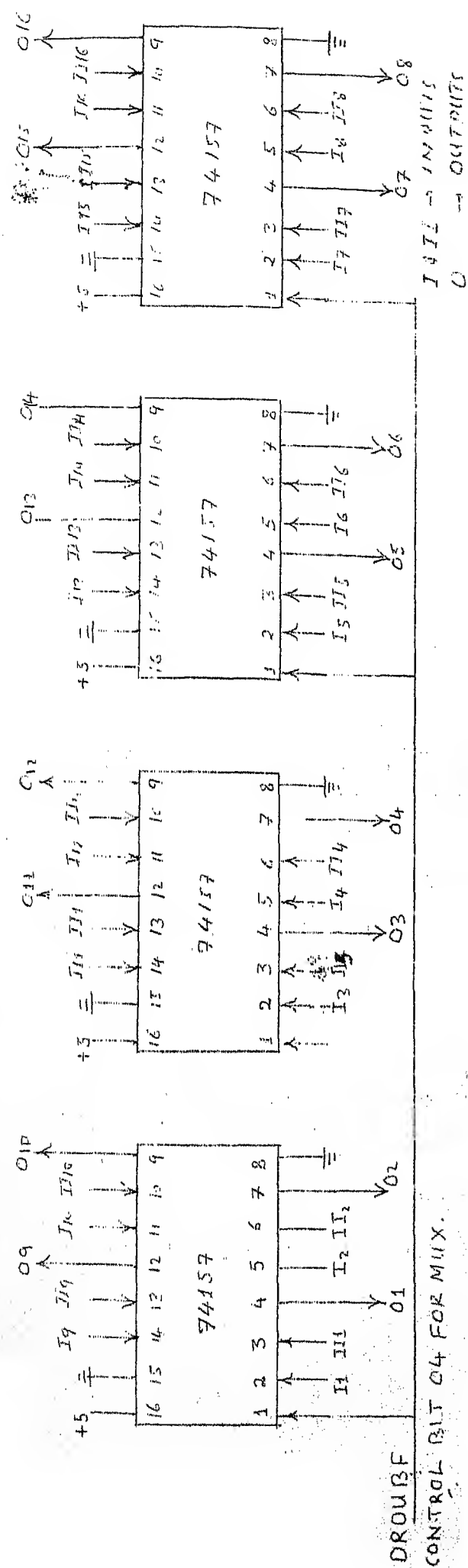
The complete experiment is dependent to this clock for time event generation for execution. It works on Model (repeated interval) using 100 KHz crystal.



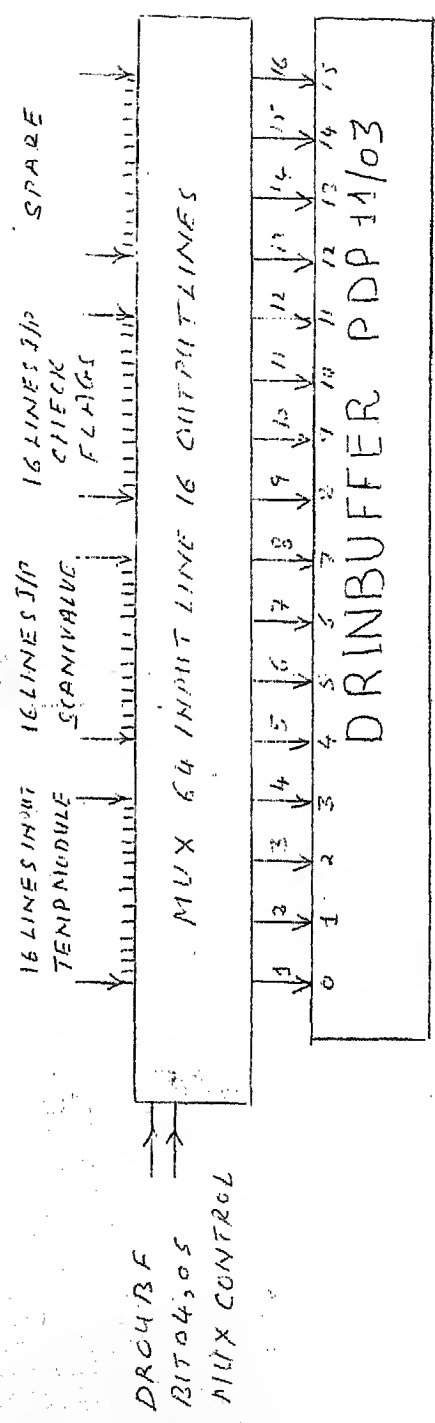
APPENDIX A Fig.1.1 PDP 11/03 BASED DATA ACQUISITION AND CONTROL SYSTEM CONFIGURATION



APPENDIX A Fig.1.2 BIT UTILISATION DETAILS OF 16 BIT PARL.I/O



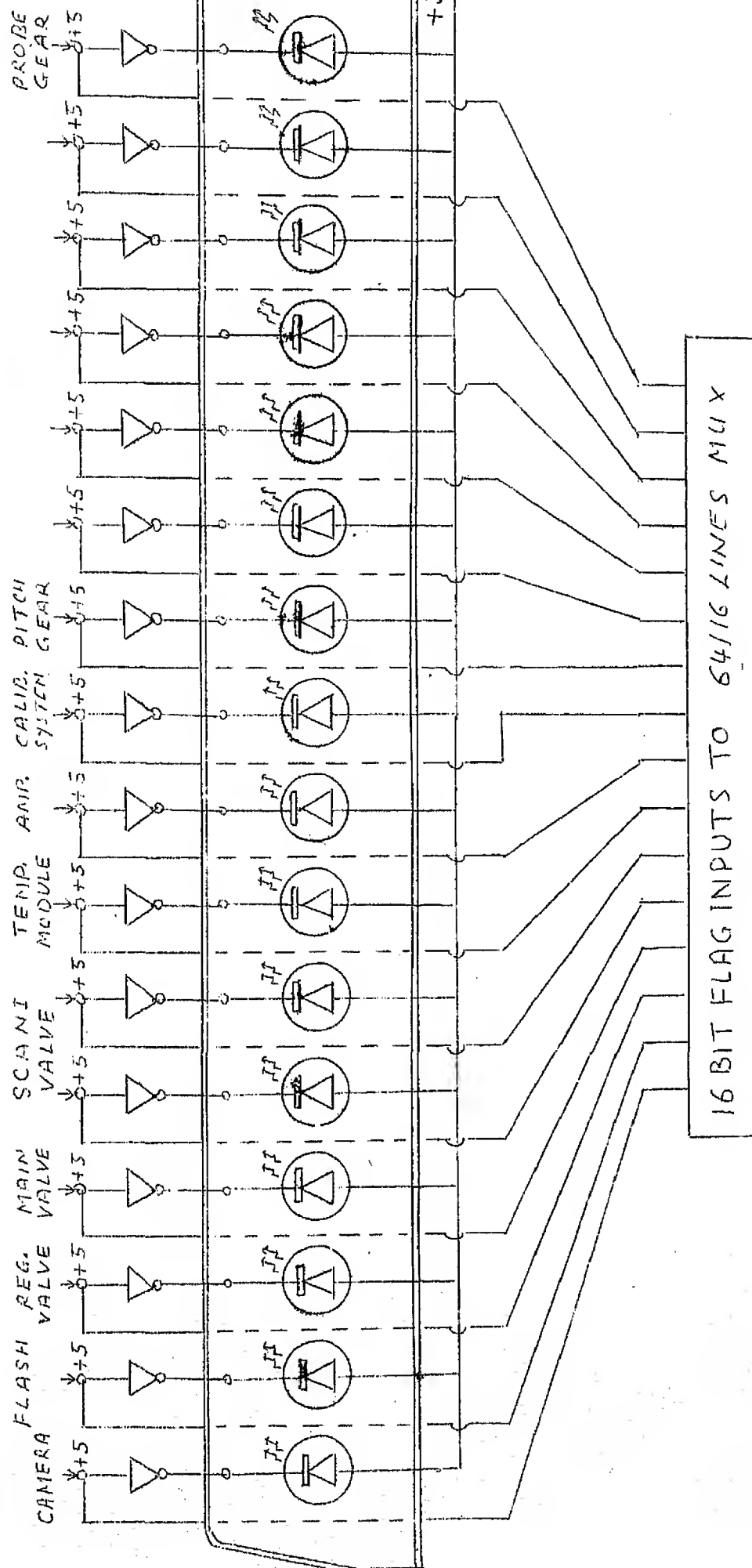
32 BITS INPUT 16 BITS OUTPUT MUX TO DRIVE

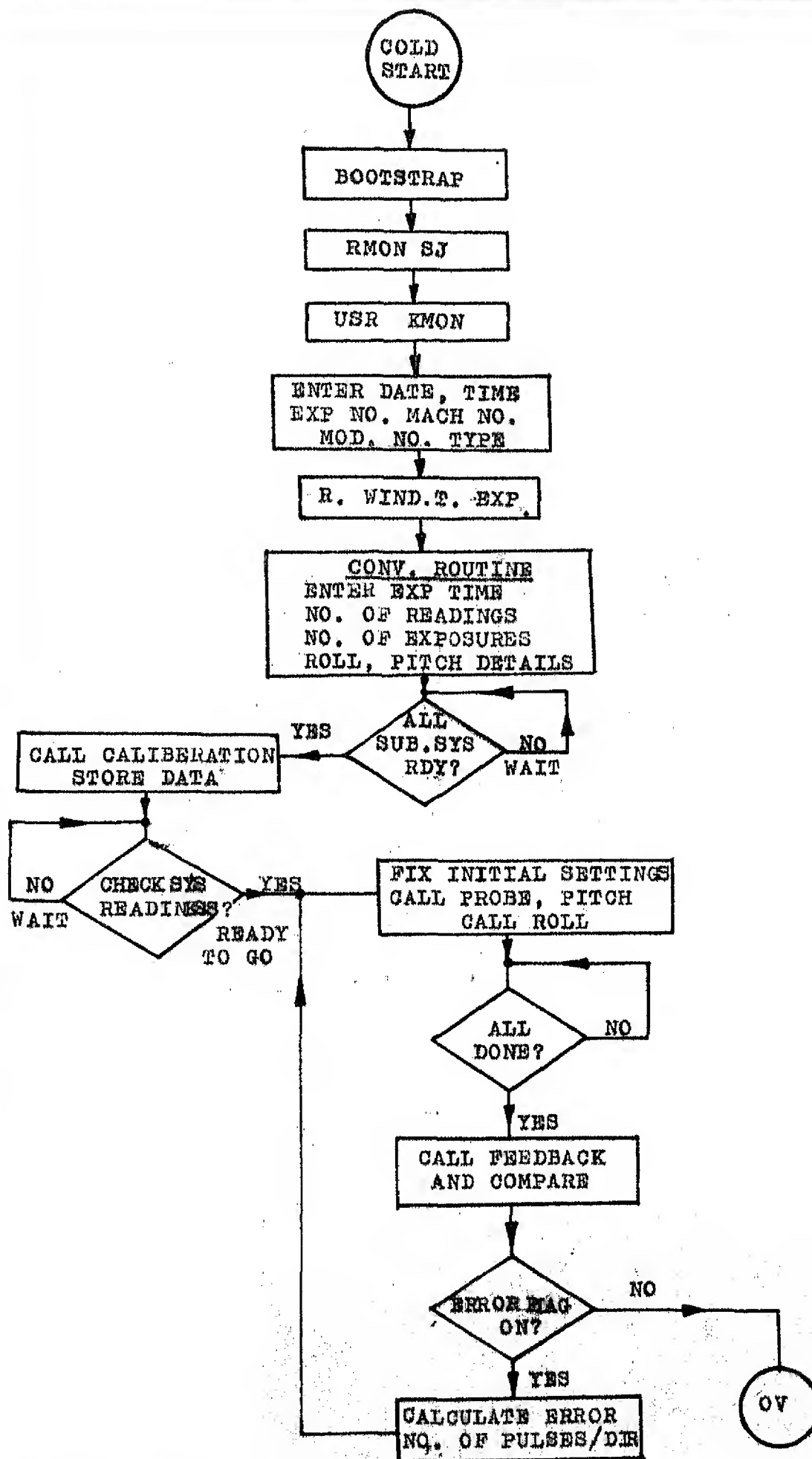


MUX DETAILS TO INCLUDE AUTOMATIC FLAG CHECK

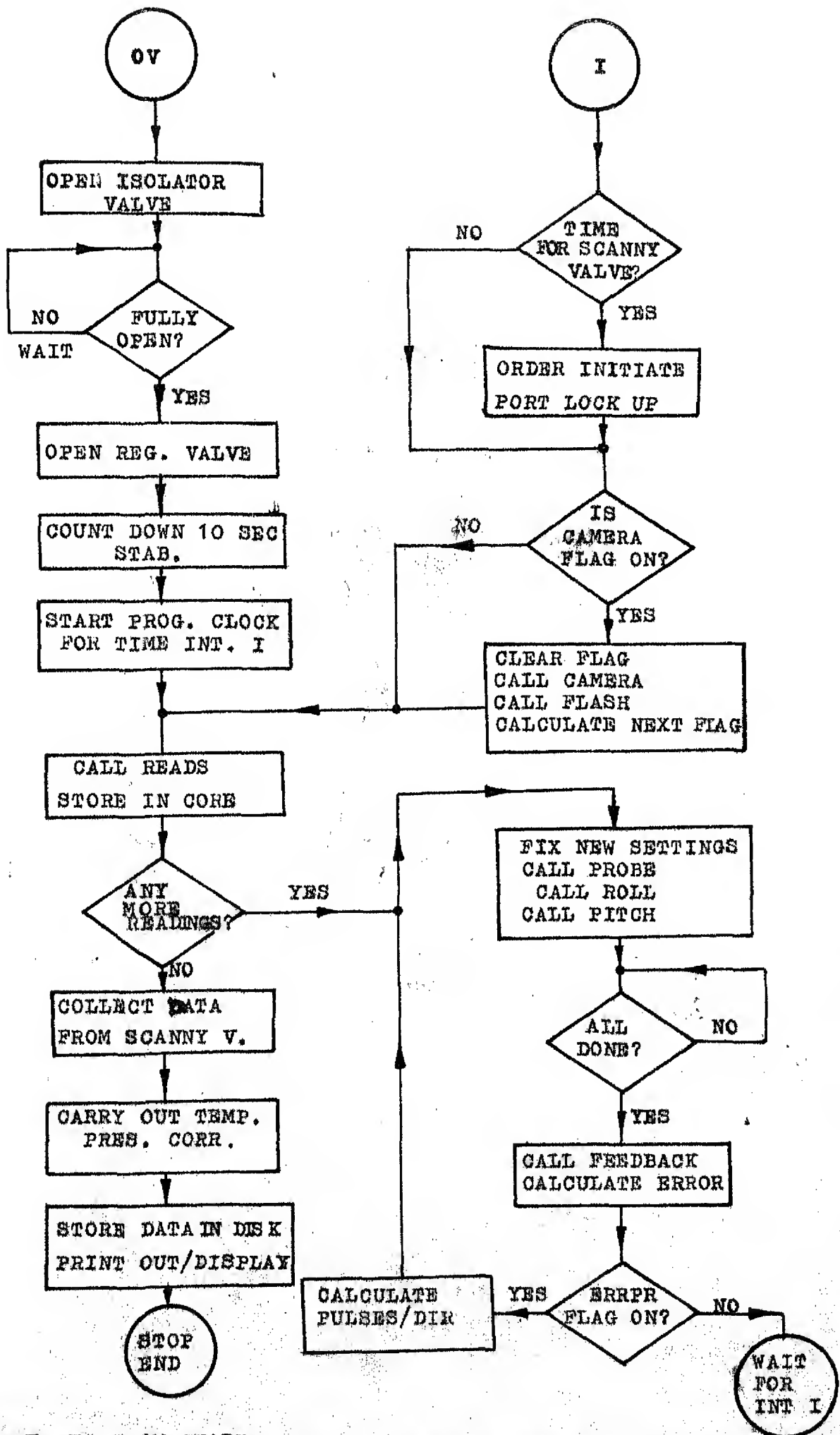
FIG. 1,2. APPENDIX "A".

INPUTS OF SUBSYSTEMS READINESS





EXP. R- EXP FLOW CHART



EXP.F:EXP FLOW CHART

APPENDIX C

```

// FOR ROTS
*IOCS (CARD,TYPEWRITER,DISK,KEYBOARD)
*ONE WORD INTEGERS
    EXTERNAL GEN
    COMMON/INSKEL/I11,N11,K11,IPOSE(3),L11,CALO1,CALO2
    COMMON IC(100),M(10),N(25),IFLAG,IDATA(3)
    DEFINE FILE 1(100,1.U.ICE)
C    CALO1 IS THE READING OF AMP. ZERO OFFSET
C    CALO2 IS THE AMP. GAIN
C    CALO3 IS THE UNCORRECTED AMP. ANALOG INPUT READING
C    IKAM ARE THE TABLE VALUES FOR DO FOR CONTACT OPERATE
    IKAM(3)=2
C    121 IS THE CO ADDRESS
    IKAM(2)=127
C    IKAM(1)=0 IS DONE FOR INETIALIZATION
    IKAM(1)=0
C    IPOSE ARE THE TABLE VALUES FOR POSITION DO
    IPOSE(3)=2
C    IPOSE 2)=121 GIVES THE DO ADDRESS
    IPOSE(2)=121
C    IPOSE(1)=0 IS FOR INETIALIZING
    IPOSE(1)=0
    N11=1
    K11=1
    L11=1
    CALL UNMK(-1,-1)
    CALL CON
    CALL CAL
    CALL PIT
C    DELAY PORTION
C    THIS PORTION GIVES 10 SECONDS DELAY AFTER REGULATOR
    VALVE HAS BEEN OPEND THEN THE EXPRIMENT STARTS
    WRITE(1,300)
300    FORMAT(//.#OPEN ISOIATOR VALVE WAIT FOR FULL ON
        INDICATION#,//)
    CALL BUSY
    WRITE(1,10)
10    FORMAT(#WIND TUNNEI DATA ACQUSITION EXP STARTS#,//,#
        PRESS START#)
    CALL BUSY
    PAUSE 124
    WRITE (1,310)
310    FORMAT(1H, #OPEN REG. VALVE THERE WILL BE 10 SEC. DELAY
        TO START#)
    CALL BUSY
    CALL DELAY (500,200)

```

```

C      CONTACT OPERATE INETIALIZATION
C      CALL CO(11001, IKAM(1), IKAM(3))
C      POSITION DO INETIALIZATION
C      CALL DO(11001, IPOSE(1), IPOSE(3))
C      SETTING FOR BIT 01=1 AND 00=1 FOR FORWARD DIRECTION
C      IPOSE(1)=3
C      IFLAG=1 IS FOR FORWARD DIRECTION
C      IFLAG=1
C      START TIME RECORD
C      CALL CLOCK(I)
C      I11=I
C      CALL TIMER (GEN,2,1000)
15     IF(LD(5))15,20,20
20     CONTINUE
C      CALL VIAQ
C      END
// FOR ROT3
C      SUBROUTINE DELAY(M,N)
C      THIS ROUTINE GIVES REQUIRED DELAY FOR THE CORRECT
C      WIDTHS OF THE PULSES REQUIRED BY THE STEPPER MOTOR SYSTEM
C      DO 500 J=1,M
C      DO 500 K=1,N
500    CONTINUE
C      RETURN
C      END
// FOR ROT4
C      SUBROUTINE GEN
C      ROUTINE GEN IS THE ROUTINE WHICH CALLS LEVEL 8 ROUTINE
C      IN TIMER
C      CALL LEVEL (8)
C      RETURN
C      END
// FOR ROT5
C      SUBROUTINE CON
C      THIS ROUTINE INSURES VARIOUS DATA ENTRY AND SUB SYSTEM
C      READYNES CONVERSATION ROUTINE AND DATA ENTRY
C      DATA TAKEN AS FOLLOWS
C      ENTER NO OF PROBE READINGS IN ONE DIRECTION -----
C      NO OF TOTAL PROBE READINGS -----
C      ENTER NO OF ANALOG READINGS OF INPUT
C      ENTER NO OF CAMERA SHOTS
C      ENTER PITCH (INETIAL) ANGLE-----DTG.TAKE OFF
C      WRITE(1,111)
111    FORMAT(111)

```

```

CALL BUSY
WRITE(1,112)
112  FORMAT(/,/#WIND TUNNEL EXPERIMENTAL SETUP DATA
      ENTRY ROUTINES#)
CALL BUSY
WRITE(1,116)
116  FORMAT(/,/#PLEASE ENTER DATA THROUGH KEY.B/CONSOLE BOARD#)
CALL BUSY
WRITE(1,113)
113  FORMAT(/,/#ENTER NO OF PROBE READINGS-----40#)
CALL BUSY
READ(2,223)IX
223  FORMAT(I2)
WRITE(1,114)
114  FORMAT(/,/#ENTER NO OF CAMERA READINGS----20#)
CALL BUSY
READ(2,223)IX
WRITE(1,115)
115  FORMAT(/,/#ENTER INITIAL AIRCRAFT PITCH---15 DEG.TAKE OFF#)
CALL BUSY
READ(2,223)IX
WRITE(1,111)
CALL BUSY
WRITE(1,101)
101  FORMAT(/,/#ANSWER 1 FOR YES,ANY OTHER NO FOR NO#./)
CALL BUSY
WRITE(1,201)
200  FORMAT(/,/#IS CAMERA ON#./)
201  CALL BUSY
READ(2,11)IA1
11   FORMAT(I1)
IF(IA1-1)300,12,300
300  WRITE(1,91)
91   FORMAT(1H,/#SWITCH ON CAMERA SYSTEM#./)
CALL BUSY
GO TO 200
12   WRITE(1,210)
210  FORMAT(1H,/#IS AMPLIFIER ON#./)
CALL BUSY
READ(2,11)IA2
IF(IA2-1)400,13,400
400  WRITE(1,92)
92   FORMAT(1H,/#SWITCH ON THE AMP SYSTEM AND LET IT
      STABILIZE#./)
CALL BUSY
GO TO 12
13   WRITE(1,220)

```

```

220  FORMAT(1H, #IS PROBE DRIVE SYSTEM ON#, /)
      CALL BUSY
      READ(2, 11) IA3
      IF(IA3-1) 500, 14, 500
500  WRITE(1, 93)
93   FORMAT(1H, #SWITCH ON THE PROBE DRIVE SYSTEM#, /)
      CALL BUSY
      GO TO 13
14   WRITE(1, 230)
230  FORMAT(1H, #IS SCANNY VALVE SYSTEM ON#, /)
      CALL BUSY
      READ(2, 11) IA4
      IF(IA4-1) 600, 15, 600
600  WRITE(1, 94)
94   FORMAT(1H, #SWITCH ON THE SCANNY VALVE SYSTEM#, /)
      CALL BUSY
      GO TO 14
15   WRITE(1, 240)
240  FORMAT(1H, #IS PITCH DRIVE SYSTEM ON#, /)
      CALL BUSY
      READ(2, 11) IA5
      IF(IA5-1) 700, 16, 700
700  WRITE(1, 95)
95   FORMAT(1H, #SWITCH ON PITCH DRIVE SYSTEM#, /)
      CALL BUSY
      GO TO 15
16   CONTINUE
      RETURN
      END
// FOR ROT6
      SUBROUTINE PIT
C     THIS ROUTINE FIXES THE PITCH OF THE AIRCRAFT
      DIMENSION IDATA(3)
      WRITE(1, 1)
1     FORMAT(//, #AIRCRAFT INITIAL PITCH BEING SET TO
          15 DEGREES#)
      CALL BUSY
C     PITCH TAKEN HERE IS 15 DEGREES TAKEOFF
      IDATA(3)=2
      IDATA(2)=120
      IDATA(1)=0
      DO 17 I=1, 10
          IDATA(I)=0
      CALL DO(11001, IDATA(1), IDATA(3))
33  CALL DO(0, ITST1)
      CALL DELAY(5, 5)
      GO TO (33, 34), ITST1

```

```

34      CONTINUE
        IDATA(1)=3
        CALL DO(11001,IDATA(1).IDATA(3))
CALL DELAY(10.10)
35      CALL DO(0,ITST1)
        GO TO (35,36),ITST1
36      CONTINUE
17      CONTINUE
        RETURN
        END
//FOR ROT7
        SUBROUTINE CALL
C        THIS ROUTINE IS USED TO CALIBRATE THE AMPLIFIERS AND
C        TO CALCULATE THE ZERO OFFSET WHICH IS USED TO
        CORRECT ANALOG READINGS
1        WRITE(1,1)
1        FORMAT(//,#GIVE ZERO INPUT TO THE AMPLIFIER#)
        CALL BUSY
        WRITE(1,2)
2        FORMAT(//,#ONCE ZERO INPUT GIVEN PRESS START#,//)
        CALL BUSY
        PAUSE129
        CALL AIP(01000,CALO1.4108)
4        CALL AIP(0,ITST2)
        GO TO(4,5),ITST2
5        CONTINUE
        WRITE(1,6)
6        FORMAT(//,#GIVE UNIT INPUT VOLTAGE TO AMP TO
        CALC. GAIN#,//)
        WRITE(1,7)
7        FORMAT(#PRESS START#,//)
        CALL BUSY
        PAUSE 126
        CALL AIP(01000,CALO2.4108)
8        CALL AIP(0,ITST2)
        GO TO (8,9),ITST2
9        CONTINUE
        RETURN
        END
*STORECI M      ROT1      ROTS      ROT1
*FILES(1,FILE1,0)
*CCEND

// JOB
// DUP
// FOR ROTSS
*IOCS(TYPEWRITER,DISK)
*ONE WORD INTEGERS

```

```

      INTEGER CALO3
      REAL X
      EXTERNAL GEN
      COMMON/INSKEL/111,N11,K11,IPOSE(3),IKAM(3),L11,CALO1,
        CALO2
      COMMON IC(100),M(10),N(25),IFLAG,IDATA(3)
      DEFINE FILE 1(100,1.U,I3)
      DO 98 I=1,10
      CALL DO(11001,IPOSE(1),IPOSE(3))
94      CALL DELAY(5,20)
94      CALL DO(0,ITST1)
      GO TO(94,96),ITST1
96      IF(2-IFLAG)101,101,102
102      IPOSE(1)=2
      GO TO 103
101      IPOSE(1)=0
      CALL DO(11001,IPOSE(1),IPOSE(3))
      IPOSE(1)=1
      GO TO 97
103      CALL DO(11001,IPOSE(1),IPOSE(3))
      IPOSE(1)=3
97      CALL DO(0,ITST1)
      GO TO(97,98),ITST1
98      CONTINUE
      CALL CLOCK(I)
      IC(L11)=1
      CALL AIP(01000,CALO3,4108)
111      CALL AIP(0,ITST2)
      GO TO (111,112),ITST2
112      L11=L11+1
      IC(L11)=CALO3-CALO1
      IF(20-N11)330,552,340
340      IPOSE(1)=3
      IFLAG=1
      GO TO 341
      52      WRITE(1,551)
551      FORMAT(/,"*****REVERSE DIRECTION MOVEMENT****#,/)
      CALL BUSY
330      FLAG=2
      IPOSE(1)=1
341      K2=2*K11
      IF(K2-N11)600,410,420
410      IKAM(1)=2
      CALL CO(11001,IKAM(1),IKAM(3))
222      CALL CO(0,ITST3)
      GO TO (222,223),ITST3
223      IKAM(1)=0

```

```

CALL CLOCK(I)
L11=L11+1
IC(L11)=I
K11=K11+1
IF(40-N11)600,600,420
420 N11=N11+1
L11=L11+1
CALL DELAY(20,20)
CALL CO(110011,IKAM(1),IKAM(3))
CALL TIMER(GEN,2,1000)
77 IF(LD(5))77,78,78
78 CALL INTEX
600 CALL CLOCK(I)
I12=I-111
WRITE(1,14)I11,I12
14 FORMAT(1H,/#START TIME#,15,/# FINISH TIME#,15,/)
CALL BUSY
WRITE(1,16)
16 FORMAT(/# PTIME#,/# ANALOG IP #,/# FTIME#,/)
CALL BUSY
J1=1
JJ=1
33 GO TO(18,19),JJ
18 IC1=IC(J1)
J1=J1+1
IC2=IC(J1)
X=IC2
X=(X*5.5)/32768
WRITE(1,21)IC1,X
21 FORMAT(15,3X,F9,5)
CALL BUSY
JJ=2
GO TO 99
19 IC1=IC(J1)
J1=J1+1
IC2=IC(J1)
X=IC2
X=(X*5.0)/32768
J1=J1+1
IC3=IC(J1)
WRITE(1,22)IC1,X,IC3
22 FORMAT(15,3X,F9,3X,16)
CALL BUSY
JJ=1
99 IF(100-J1)114,114,113
113 J1=J1+1
GO TO 33

```

```

114      WRITE(1,23)
23      FORMAT(//, #STORING OF DATA ON DISKO FILE1 STARTS#, //)
      CALL BUSY
      DO 555 J1=1,100
      WRITE(1#1)IC
555      CONTINUE
      WRITE(1,25)
25      FORMAT( #***EXPERIMENT OVER DATA IS SAFELY TUCKED
      IN DISK***#)
      CALL BUSY
      CALL INTEX
      END
//FOR ROT3
      SUBROUTINE GEN
      CALL LEVEL (8)
      RETURN
      END
//FOR ROT1
      SUBROUTINE DELAY(M,N)
      DO 500 J=1,M
      DO 500 K=1,N
500      CONTINUE
      RETURN
      END
//DUP
*STORECI I R1 ROTSS ROT1
*FILES(1,FILE1,0)
*CCEND
//DUP

```

APPENDIX D

```

WINDTL.BAS
5 REM-*****
10 REM--WINDTUNNEL DATA ACQUISITION AND CONTROL SYSTEM ROUTINES
15 REM-
20 REM--BEGINNING OF CONVERSATION AND DATA ENTRY ROUTINES
25 DIM A1(50),A2(50),A3(50)
30 PRINT "WELCOME TO TRISONIC WINDTUNNEL SYSTEM OF AERO ENGG"
35 PRINT "                DEPT. OF I.I.T.K."
40 REM-
50 PRINT "PLEASE FOLLOW THE INSTRUCTIONS CORRECTLY"
60 PRINT
70 PRINT "PLEASE ENTER ON CONSOLE DATE,EXP.NO.,MACH NO.,MOD.NO".
80 PRINT
90 PRINT "DATE? DD-MM-YY(EG.05-MAY-78)"
100 INPUT A1$
110 PRINT "EXPERIMENT NO"
120 INPUT A2$
130 PRINT "MACH NO."
140 INPUT A3$
150 PRINT "EXPERIMENT DONE BY"
160 INPUT A4$
170 PRINT
180 PRINT "PLEASE ENTER EXPERIMENT PARAMETERS"
190 PRINT
200 PRINT "DURATION OF THE EXPERIMENT IN SECOND (INTEGER)"
210 INPUT N1
220 PRINT
230 PRINT "TOTAL NUMBER OF PROBE"
240 INPUT N2
245 PRINT
250 PRINT "NUMBER OF TEMPERATURE PROBE READINGS"
260 INPUT N4
265 PRINT
270 PRINT "NUMBER OF CAMERA SHOTS"
280 INPUT N5
290 PRINT
300 PRINT "INITIAL PITCH IN STEPS(1 STEP=1.8 DEGREES)"
310 INPUT N6
320 PRINT
330 PRINT "INCREMENTAL PITCH STEPS-0 FOR NO CHANGE"
335 INPUT N7
340 REM-*****
345 REM-
350 REM-SUBASSEMBLIES CHECK ROUTINES
360 REM-THESE ROUTINES ARE TEMPORARY AND WILL BE REPLACED BY

```

```
370 REM--AUTOMATIC FLAG CHECKS
380 PRINT
390 PRINT "PLEASE ANSWER Y OR N FOR YES OR NO"
400 LET B1$="Y"    B2$="N"
410 PRINT
420 PRINT "IS DC POWER SUPPLY SYSTEM ON"
430 INPUT C$
440 IF C$=B1$ THEN 480
450 IF C$=B2$ THEN 470
460 PRINT
465 PRINT "PLEASE TYPE Y OR N"
470 PRINT "PLEASE SWITCH ON DC SUPPLY" \ GO TO 420
480 PRINT
490 PRINT "IS SCANIVALVE SUB SYSTEM READY"
500 INPUT C$
510 IF C$=B1$ THEN 560
520 PRINT
525 PRINT "DO YOU NEED SCANIVALVE IN THIS RUN"
530 INPUT C$
540 IF C$=B2$ THEN 560
550 PRINT "PLEASE SWITCH ON SCANIVALVE SUB SYSTEM" \ GO TO 490
560 PRINT
565 PRINT "PRINT "IS PROBE DEIVE SUBSYSTEM READY"
570 INPUT C$
580 IF C$=B1$ THEN 640
590 PRINT
600 "DO YOU WANT THE PROBE MOVEMENT"
610 INPUT C$
620 IF C$=B2$ THEN 640
630 PRINT
635 PRINT "PLEASE SWITCH ON PROBE DRIVE SUBSYSTEM" \ GO TO 565
640 PRINT
645 PRINT "IS MODEL ATTITUDE GEAR SYSTEM READY"
680 INPUT C$
690 IF C$=B1$ THEN 720
700 PRINT
710 PRINT "PLEASE SWITCH ON THE PITCH DRIVE SUBSYSTEM" GO TO 645
720 PRINT
725 PRINT "IS CALIBRATION SUBSYSTEM READY"
730 INPUT C$
740 IF C$=B1$ THEN 760
750 PRINT
755 PRINT "PLEASE SWITCH ON CALIBRATION SYS.FOR STAB." GO TO 725
760 PRINT
765 PRINT "IS ANALOG SUBSYSTEM READY"
```

```

770 INPUT C$
780 IF C$=B1$ THEN 800
795 PRINT "PLEASE SWITCH ON ANALOG SUBSYSTEM" GO TO 765
800 PRINT
810 PRINT "IS CAMERA/FLASH SUB SYSTEM READY? PLEASE SET  APER-"
815 PRINT "TURE,SPEED, AUTO,NO OF FRAMES"
820 INPUT C$
825 IF C$=B1$ THEN 880
830 PRINT
835 PRINT "DO YOU WANT SNAPS TO BE TAKEN"
840 INPUT C$
850 IF C$=B2$ THEN 880
860 PRINT "PLEASE SWITCH ON CAMERA/FLASH SUB SYS,ADJUSTMENTS"
865 GO TO 810
868 REM-*****
869 REM-
870 REM-BEGINNING OF CALIBRATION ROUTINE
880 PRINT
890 PRINT "YOU NEED ADJUSTING ZERO OFFSET OF PROBE AMP."
895 PRINT "PLEASE DISCONNECT PROBE INPUT TO AMP.,FEED ZERO TO"
900 PRINT "AMP INPUT ADJUST ZERO OFFSET FOR ZERO O/P"
910 PRINT "WHEN FINISHED TYPE OK ON TERMINAL"
920 LET E$="OK"
930 INPUT C$
940 IF C$=E$ THEN 950
945 GO TO 890
950 PRINT "PLEASE FEED UNIT INPUT TO ADD INPUT SAY OK WHEN DONE"
960 INPUT C$
970 IF C$=E$ THEN 980
975 GO TO 950
980 CALL "ADC" (0,G1)
990 PRINT "PLEASE NOW FEED UNIT INPUT TO AMP AND CONNECT O/P TO"
995 PRINT "ADC OF 11/03, SAY OK WHEN DONE"
1000 INPUT C$
1010 IF C$=E$ THEN 1020
1015 GO TO 990
1020 CALL "ADC" (0,G2)
1040 G=G2/G1
1050 PRINT
1055 REM-*****
1058 REM-FINAL CHECK,PARAMETER CALC.,INETIAL FIXATION ROUTINES
1060 PRINT "IS SYSTEM READY IN ALL RESPECTS TO START"
1070 INPUT C$
1080 IF C$=B1$ THEN 1115
1090 GO TO 1060
1110 PRINT
1115 PRINT "FIX MODEL & PROBE TO INETIAL ZERO REF POINT,TYPE OK"

```

```

1120 INPUT C$
1130 IF C$=E$ THEN 1150
1140 GO TO 1110
1150 T=(N1/N2)*100000
1155 T=INT(T)
1160 N3=INT(200/N2)
1165 REM--N3 IS THE NO OF STEPS TO BE MOVED BY PROBE AT A TIME
1170 IF N3 <=20 THEN 1180
1175 N9=1
1180 IF N6 >=0 THEN 1200
1190 B=1 GO TO 1400
1200 B=0
1300 REM--INITIAL SETTING OF MODEL ATTITUDE IS TO BE DONE
1400 CALL "PITH" (N6,B)
1420 REM--
1430 REM--*****
1440 REM--
1450 REM--BEGINING OF CONTROL AND ACQUISITION ROUTINES
1500 PRINT
1600 PRINT "THE EXPERIMENT WILL NOW BEGIN WITH OPENING OF
      MAIN VALVE"
1610 PRINT "FOLLOWED BY REGULATOR VALVE AFTER SENSING FULL OPEN"
1620 PRINT "FLAG, THIS IS FOLLOWED BY 10 SECONDS OF STABLE.."
1630 PRINT "ISATION DELAY AND THERE AFTER THE EXPERIMENT"
1700 CALL "VALV"
1800 CALL "SETC" (5,10)
1900 CALL "WAIT" (0)
2000 I=0 \ I1=1
2050 CALL "SETR" (2,0,T)
2100 FOR N=1 TO N2
2200 I=I+1 \ I1=I1+1
2300 CALL "ADC" (0,C)
2350 A1(N)=C
2400 CALL "TEMP" (C)
2450 A2(N)=C
2600 IF N=1 THEN 3000
2700 IF N9=1 THEN 3000
2800 IF I < 3 THEN 3100
2900 I=1
3000 CALL "CAMR"
3100 IF N < 21 THEN 3300
3200 B=1
3300 CALL "PROB" (N3,B)
3400 IF N=20 THEN 3600
3500 GO TO 4000

```

```

3600 CALL "SCAN" (0,C)
3700 IF N7=0 THEN 4200
3800 B=1
3900 CALL "PITH" (10,B)
4000 IF I1 < 3 THEN 4200
4100 CALL "PITH" (N7,B)
4150 I1=1
4200 CALL "WAIT" (0)
4300 NEXT N
4400 REM-*****
4450 REM DATA COLLECTION/CONVERSION ROUTINES
4500 PRINT
4550 PRINT "EXPERIMENT IS OVER,SCANIVALVE DATA COLLECTION,CONV"
4560 PRINT "ERSION OF TEMP.BCD DATA STARTS"
4600 REM-*****
4700 REM-SCANIVALVE COLLECTION AND CONVERSION ROUTINE
4750 FOR N=1 TO 48
4800 A7=0 A8=1
5000 CALL "SCAN" (1,C)
5100 A4=C
5150 A3(N)=C
5200 IF A4=0 THEN 6000
5300 A5=INT(A4/16)
5400 A6=A4-(A5*16)
5500 A7=A7+(A6*A8)
5600 IF A5=0 THEN 5900
5700 A8=A8*10
5800 A4=A5 GO TO 5300
5900 A3(N)=A7
6000 NEXT N
6025 REM-*****
6050 REM-TEMPERATURE BCD TO DECIMAL DATA CONVERSION
6100 FOR N=1 TO N2
6200 A7=0 A8=1
6400 A4=A2(N)
6500 IF A4=0 THEN 7200
6600 A5=INT (A4/16)
6700 A6=A4-(A5*16)
6750 A7=A7+(A6*A8)
6800 IF A5=0 THEN 7100
6900 A8=A8*10

```

```
7000 A4=A5 GO TO 6600
7100 A2(N) = A7
7200 NEXT N
7300 PRINT
7400 PRINT
7450 PRINT A1$
7460 PRINT A2$
7470 PRINT A3$
7480 PRINT A4$
7490 PRINT
7500 PRINT "S.NU.    PRESS.    TEMP    SCAN1.PR"
7600 FOR I=1 TO 50
7700 PRINT 1,A1(1),A2(1),A3(1)
7750 NEXT 1
7800 END
*
```

=FUN4.MAC

FUNA--ASSEMBLY FUNCTIONS

- . TITLE FUN4
- . GLUBLE VALVEN, PRUBFN, PITHFN, CAMRFN
- . GLUBL TEMPFN, INT, STORE

```

RO=Z0    %0
R1=Z1    %1
R2=Z2    %2
R3=Z3    %3
R4=Z4    %4
R5=Z5    %5
SP=Z6    %6
PC=Z7    %7
OUBF=167772
INBF=167774
DRCSR=167770
FAC1= 40
FAC2= 42
; "VALV"
VALVEN: CLR OUBF
        BIS #010000, OUBF
X1:     TSTB DRCR
        BPL X1
X2:     BIS #020000, OUBF
        RTS PC
; "CAMR"
CAMRFN: CLR OUBF
        MOV #20000, R2
        BIS #140000, OUBF
        RTS PC
; "PITH" (A,B)
PITHFN: CLR OUBF
        MOV #TABLE, RO
        JSR PC, GETARG
        .BYTE 1,1,0
        .EVEN

        MOV A1, FAC1, (R5)
        MOV A2, FAC2 ( R5)
        JSR PC, INT
        MOV FAC2 (R5), R2
        MOV B1, FAC1 (R5)
        MOV B2, FAC2 (R5)

```

```

        JSR PC, INT
        MOV FAC2 (R5), R3
X4:     MOV #750,R4
X5:     TSTB R2
        REQ X21
        TSTB R3
        BEQ X6
        BIS #0003000, OUBF
        BR X7
X6:     BIS #000100, OUBF
X7:     DEC R4
        TST R4
        BNE X7
        CLR OUBF
        MOV #250,R4
X8:     DEC R4
        TST R4
        BNE X8
        DEC R2
        BPL X4
X21:    RTS PC

```

```

; "PROB" (A,B)
PROBFN: MOV #TABLE,R0
        JSR PC, GETARG
        .BYTE 1,1,0
        .EVEN
        MOV A1,FAC1 (R5)
        MOV A2, FAC2 (R5)
        JSR PC, INT
        MOV FAC2 (R5), R2
        MOV B1, FAC1 (R5)
        MOV B2, FAC2 (R5)
        JSR PC, INT
        MOV FAC2 (R5),R3
        CLR OUBF

```

```

X9:     MOV #750,R4
        TSTB R2
        BEQ      X20
X10:    TSTB R3
        BIS #000003, OUBF
        BR X12
X11:    BIS #000001, OUBF
X12:    DEC R4
        TST R4
        BNE X12

```

```

                CLR OUBF
                MOV #250,R4
X13:            DEC R4
                TST R4
                BNE X13

X14:            DEC R2
                BPL X9
                CLR OUBF
X20:            RTS PC

; "TEMP" (C)
TEMPFN:         CLR OUBF
                MOV #TABLE, RO
                JSR PC, GETARG
                .BYTE 2,0
                .EVEN
                BIS #001000, OUBF

                CLR FAC1 (R5)
                MOV INBF, FAC2 (R5)
                MOV #A1, RO
                JSR PC, STORE
                CLR OUBF
                RTS PC

; "SCAN" (A,C)
SCANFN:         MOV #TABLE, RO
                JSR PC, GETARG
                .BYTE 1,2,0
                .EVEN
                MOV A1, FAC1 (R5)
                MOV A2, FAC2 (R5)
                JSR PC, INT
                MOV FAC2 (R5), R2
                TSTB R2
                BNE X15
                CLR FAC1 (R5)
                CLR OUBF
                BIS #002000, OUBF
                MOV INBF, FAC2 (R5)
                MOV #B1, RO
                JSR PC, STORE
                BR      X16
X15:            BIS #004000, OUBF
X16:            RTS PC

```

TABLE:

```

A1: .WORD 0
A2: .WORD 0
B1: .WORD 0
B2: .WORD 0
C : .WORD 0
      .END

```

FUN3.MAC

```

      .GLOBL VALVFN, PRUBFN, PITHFN, SCANFN, TEMPFN
      .CSECT BASICR
      .WORD FUNTAB
      .CSECT FUN1
FUNTAB: .ASCII 'VALV'
      .WORD VALVFN
      .ASCII 'PRUB'
      .WORD PRUBFN
      .ASCII 'PITH'
      .WORD PITHFN
      .ASCII 'CAMR'
      .WORD CAMRFN
      .ASCII 'SCAN'
      .WORD SCANFN
      .ASCII 'TEMP'
      .WORD TEMPFN
      .END

```

APPENDIX E

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